SHAW'S

CIVIL ARCHITECTURE;

BEING

A COMPLETE THEORETICAL AND PRACTICAL

SYSTEM OF BUILDING,

CONTAINING

THE FUNDAMENTAL PRINCIPLES OF THE ART,

AND

ILLUSTRATED BY EIGHTY-TWO COPPERPLATE ENGRAVINGS.

BY EDWARD SHAW, ARCHITECT.

SIXTH EDITION, REVISED AND IMPROVED.

TO WHICH ARE ADDED

TWENTY COPPERPLATE ENGRAVINGS,

ALSO,

A TREATISE ON GOTHIC ARCHITECTURE, WITH PLATES, &c

BY THOMAS W. SILLOWAY AND GEORGE M. HARDING,

ARCHITECTS.

BOSTON:

PUBLISHED BY JOHN P. JEWETT AND COMPANY

CLEVELAND, OHIO: JEWETT, PROCTOR, AND WORTHINGTON.

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TO THE FIRST EDITION.

It is obvious that most writers on Civil Architecture have not entered into those mathematical principles on which this noble art ultimately rests, and from which it derives its very existence. They may rather be said to consider it merely as an art than as a science also, and are more calculated to instruct the student in drawing architectural plans than to point out and elucidate those unalterable rules and first principles which, however unperceived, (as Mr. Nicholson justly observes,) must enter into the very essence of every plan that is correct and practicable.

The student, in the outset, should commence his inquiry by going back to the most simple elements of mathematical knowledge, there to obtain the real clew to his future studies, and from thence, gradually and scientifically, to proceed to more complex problems and more diversified plans. On this principle is founded the superior skill of the Grecian and Roman artists, which has, as yet, been unrivalled.

We should not content ourselves by merely drawing from their works, and then superadding the invention of our own imagination; but we should continually recur to the ground on which they trod, and make that the criterion of all our attempts. It is principally to assist the practical mechanic, as well as the student, that this work has been projected; and, as will appear, much pains have been taken to lay down the fundamental principles of architecture in a clear, distinct, and intelligible manner, and to apply the whole to practice by plain and obvious examples and illustrations. I have endeavored to arrange the contents so as to be useful to the student, as well as to all classes of operative builders.

Those workmen, therefore, who aspire to any degree of superiority and taste in either of these branches, will be able from hence, by improving their leisure hours, in a short time to understand the principles of their respective occupations, and to execute with taste and pleasure what they do now but mechanically.

In this work is given whatever the experience of the most judicious professors has sanctioned as the best mode of affecting their professional purposes, with the reasons on which that preference is founded. To this are added examples both of Grecian and Roman antiquities, and remarks on the beauties of each. Particular attention is paid to the theory of shadows, both from direct and reflected light, and examples adduced of the relative degrees of light and shade on different surfaces, variously inclined to the luminary and the eye. Also, a select set of problems are drawn from Nicholson's writings, entirely new, and all intimately connected with the subject in hand.

They are disposed in methodical order, and are preceded by the necessary definitions. It is not intended by this part wholly to set aside the study of Euclid and authors who have written on Conic Sections. An attentive perusal of their works will always amply repay the student's trouble.

When the vast importance and utility of Geometry are considered, the student will never regret any pains he may take to make himself thoroughly master of every part of it. Particular attention has been paid to ellipses and curves — the problems relating to which will be found particularly useful in describing elliptical and Gothic arches, finding their joints, and describing mouldings of every degree of curvature, under various circumstances, with Conic Sections; also, the Sections of Solids, a thorough acquaintance with them being absolutely necessary for understanding the theory and disposition of shadows, the explanation of which will be highly gratifying to every scientific reader.

In view of the present taste for architectural knowledge, and the inadequacy of means to obtain that science, arising from the costly and voluminous works on the subject, I have been chiefly induced to compile a work of this kind. Being fully convinced of its utility, from very arduous research into its constituent principles, from my early apprenticeship to the present time, — having had more than twenty years' practice in the art of building, — I have brought together the following system in a concise but intelligible manner, which consists principally of extracts from Vitruvius, Stuart, Chambers, Nicholson, and other authors of eminence. If I have made a judicious arrangement of the several subjects, I have accomplished all I anticipated; and under these considerations, therefore, I submit this work to the public for their approbation and patronage.

EDWARD SHAW.

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TO THE SIXTH EDITION.

Being encouraged by the rapid and extensive sale of the five former editions of this work, and the urgent calls made in consequence of its having been out of print for several years, I have been induced by the advice of my friends to secure the valuable services of Messrs. Silloway and Harding, architects of Boston, gentlemen well versed in the science they profess, to assist in revising the fifth edition, and prepare additional drawings for a sixth, which has resulted in the exclusion of several of the old plates, and the substitution of twenty new ones of a character in keeping with the improvements of the day, and of great practical use to the carpenter and builder, among which are four plates of Gothic details selected from Pugin, one of the best of the English authors on this subject.

The sixth edition, thus improved and enlarged, I now offer for the attention and patronage of an enlightened public.

EDWARD SHAW.

January 1, 1852.

CONTENTS.

INTRODUCTION.

The term *Architecture* is originally derived from the Greek language, in which it signifies the principal handicraft, or mechanical operation; an expression very applicable to the construction of habitations for civilized men, without which few of the other practical arts could be desirable, or, indeed, of any value whatever. In the genial climates of the interior of Asia, where human beings first appeared, defence from the inclemency of the weather was not an object of research. Shelter from the intense rays of the sun and from the torrents of rain peculiar to those climates; protection from the wild beasts of the field; the necessity of privacy and complete separation from their fellow-creatures, — these and other motives, which might easily be specified, would, nevertheless, render architecture, however rude and simple, one of the earliest arts of life. From the Hebrew Scriptures, we learn that it had arrived at considerable perfection, even under the second generation of mankind; for there we learn that Cain, after the murder of his brother, withdrew from the habitation of his parents, and built a city in a remote quarter of the world.

The progress of architecture from rudeness to refinement is thus related by Vitruvius, whose celebrated treatise on architecture appeared in Italy in the reign of Augustus Cæsar, about the beginning of the Christian era. His notions were formed on tradition and conjecture; for the writings of Moses, which contain the most ancient account of the origin of the human race and of human society, were either unknown, or generally disregarded, in his time in Europe.

"In the first times," says Vitruvius, "men lived in woods and caves; but at last, borrowing hints from the birds, which built their nests with equal ingenuity and industry, they began to form huts for themselves. These huts were probably, at first, conical, because that figure is of the most obvious construction, composed of trees or branches fixed in a circle on the ground, and joined together in a point at the top; the whole covered with reeds, leaves, and clay. Finding, however, in the course of time, this conical figure inconvenient, on account of the slope of its sides, the form of the hut was changed to that of a cube, or of a parallelopiped. Marking out the space to be occupied by the intended structure, they fixed in the ground upright trunks of trees to form the sides, filling the intervals with branches, closely interwoven, and covering the whole with clay. The sides being thus completed, four long beams were placed on the upright posts, which, being well joined at the angles, kept the sides firm, and likewise served to support the covering or roof of the building, composed of other beams, on which were laid beds of reeds, leaves, and clay. When the art of constructing habitations was so far advanced, men bethought themselves of methods of rendering their dwellings not only commodious for present use, but elegant and durable. They stripped the bark and other inequalities from the trunks and branches employed in the walls, raised them above the damp ground by placing them on flat stones, and covered each post with a flat stone, to throw off the rain. The spaces between the ends of the joists were closed with clay, and the ends of the joists themselves were covered with thin boards, cut in the form of what are called *triglyphs*. The position of the roofs was also altered. Being flat, they were ill calculated for throwing off the rain; they were therefore raised up in the middle, so as, with the horizontal beams connecting the uprights of the walls, to form a triangular pediment or gable. From these simple elements, architecture took its beginning; for when wood was found inconvenient for constructing durable dwellings, and men set themselves to erect more solid and extensive buildings of clay dried in the sun, or stone, they still imitated the forms of those parts which

necessity had originally introduced. The upright posts, with the flat stones under and above them, were converted into columns with their bases and capitals; the beams, rafters, and layers of materials composing the roof were gradually improved into architraves, friezes, triglyphs, cornices, and the other ornamental parts of modern architecture." So far Vitruvius.

It may be further remarked, that in many countries, among the rudest tribes of men, excavations and fissures of rocks, hollows of trees, and caves of the earth have served as habitations. Travellers inform us of a tree growing in Africa, the hollow of which affords a habitation for thirty negro families, which is said to be the largest tree in the world. They also inform us of a subterraneous city or cave, occupied by Moors, in which there are several hundred inhabitants. Armstrong, in his "Journal of Travels in the seat of war between Russia and Turkey," has the following observations: "The Georgian or Tartar dwellings are seldom to be found above ground. The tops are covered with beams of wood, branches of trees, and, above all, with a coat of earth, which make them level with the ground. The natives are frequently disturbed, when sitting around the fire, by the leg of some unfortunate cow or camel making its appearance down the chimney; and it is not uncommon for the lambs to fall through, and spoil whatever may happen to be cooking." But among a civilized people, the desire of seeking for more agreeable habitations must be soon felt. The nature of the climate and the materials which it more readily afforded regulated, in a great degree, the construction of the first buildings in which men sheltered themselves. According to Diodorus Siculus, the first buildings of Palestine were of reeds and canes interwoven, and so compact as not to admit of the rain and wind. Wood appears to be a material so proper for building, and so easily wrought, that men would, in all ages, employ it for these purposes, in places where it could be easily procured. The branches of trees, stuck in the ground and rudely interwoven, formed a material for constructing them. It is probable that this method of setting trees on end, and binding them together at the top and bottom, first gave rise to the idea of base and capital of columns. When these branches were daubed with clay, and covered over with leaves and turf, they presented a model of those cabins, in which, according to Vitruvius, the earliest tribes of men were accustomed to dwell. At first, before men became acquainted with edge tools of iron, trees were felled by means of fire, or by axes made of sharp stones. They undermined the trees by little at a time, by continuing a fire at their roots; and by the same means they could divide a tree into the requisite length. By degrees, however, tools for cutting and smoothing wood were invented. The tools for smoothing were at first nothing more than sharp stones, sufficiently hard and free from brittleness. Some of our North American Indians make use of the same kind of tools at the present time. "The use of bricks or masses of clay formed in moulds and dried in the sun, or baked in stoves, as the materials of buildings, is of very great antiquity, and is a sufficiently obvious invention." According to Moses, the tower of Babel was built of bricks: "Go to, let us make *bricks*, and burn them thoroughly: and they had brick for stone, and slime had they for mortar." (Gen. xi. 3.) Pliny informs us, that in the most remote ages of the Egyptians they made use of bricks for building their houses, and tiles for covering them. To employ stones for the same purpose was very natural, where they were abundant, and found in masses sufficient to be removed by manual dexterity.

Architecture is arranged in different orders and styles, according to the nations by whom, or the country in which, it was originally employed, such as the Grecian, the Roman, the Saxon, the Norman, the Saracenic or Arabian, the Gothic, &c. The Grecian architecture is divided into the Doric, the Ionic, and the Corinthian, so named from the inventors, or from those parts of Greece, or of the Grecian colonies in Asia Minor, where each kind first appeared. Roman or Italian architecture was divided into the Tuscan and the Composite — the first being employed, as it is said, by the ancient inhabitants of Tuscany, and the last being a later improvement adopted by the Romans, compounded of the two Grecian orders, the Ionic and the Corinthian.

When architecture was in its glory in ancient Greece, the Ionic was the favorite order, as being the most graceful, light, and elegant. Of this order were the temple of the Delphic oracle, the temple of Apollo, at Miletus, and the temple of Diana, at Ephesus.

> "The Ionic, then, with decent matron grace
> Her airy pillar heaved."

After the Ionic, the Corinthian was introduced, in which in attempting greater perfection, they deviated from the true simplicity of nature. It marked age of luxury and magnificence, when pomp and splendor had become the predominant passion, but had not yet extinguished the taste for the sublime and beautiful. Attempts were made to unite all these characters; but a corrupted taste, only, was pleased, a chastened judgment was not satisfied.

> "Luxuriant last,
> The rich Corinthian spreads her wanton wreath."

In the Composite order, this deviation is more remarkable. This was invented by the Italians; and, although rich and profuse in its ornaments, discovers an obvious want of correct taste and judg-

ment, and shows that the Grecians had exhausted all the principles of grandeur and beauty in the original orders. And in these they had arrived at the acme of perfection, because the Composite could not possibly have been introduced without combining all the rest; consequently, that simplicity is destroyed, which is in conformity with nature, and the great concomitant of beauty. It is said this order was first used by the Romans in their triumphal arches, to show their dominion over the people whom they conquered.*

An order in architecture consists of two principal parts — the column and the entablature, or parts supported by the column. Of these two principal parts, each consists of three subdivisions. Those of the column are the base on which it rests, the shaft, or tall tapering portion, and the capital, or ornamental part crowning the shaft. Those of the entablature are, first, the architrave, then the frieze, and above all, the cornice. Each of the smaller parts is again subdivided and distributed in various ways, according to the orders to which they belong, as existing in antique monuments, but more frequently according to the taste and fancy of the authors who have written on the subject of architecture.

The principal character of the various kinds of architecture depending on the column and its requisite accompaniments, the whole is commonly and almost universally divided into five species or orders, viz., the *Tuscan*, the *Doric*, the *Ionic*, the *Corinthian*, and the *Composite*. This distribution and arrangement would seem to have been founded on the progressive proportion, strength, and ornament of the orders; they are, however, well calculated to mislead the student and the architect, in tracing the origin and gradual advancement of each order. Without attempting to search for the commencement of either of the above orders, it is sufficient for us to know that the Grecians employed only the Doric, the Ionic, and the Corinthian; and that the Tuscan and Composite were only used in Italy — the one more rude and the other more ornamented than the Grecian orders, which occupied a middle rank. To attain, therefore, a proper knowledge of the principles of architecture, the student ought to confine himself to the three Grecian orders, not only because in them these principles are most displayed, but because of all the monuments of antiquity which have subsisted to modern times, few, perhaps none, can be pointed out in which the Roman or Italic mode of construction is certainly to be traced.

In architecture, various terms are employed in a peculiar sense, of which the following are the chief: *Column* is a Latin word, signifying, in general, a pillar or supporter of some superincumbent load; but is now confined to a round pillar, smaller above than below, and thereby closely imitating the trunk of a tree, from which it was originally drawn. When the pillar is not round and tapering, but square, and of equal dimensions above and below, it is called an *ante*. The column consists of three principal divisions: 1st, the *base*, from the Latin term *basis*, the foundation on which any thing rests; 2d, the *shaft*, or circular tapering portion; and 3d, the *capital*, from the Latin term for the head, or the principal member.

The base is subdivided into different small parts, according to the order to which the column belongs; but all the lowermost part is the *plinth*, from the Grecian term for a brick, because the ancient bricks were in general about square, and comparatively thin, resembling our paving bricks or tiles. Above the plinth lay the *torus*, a round moulding resembling a rope, so called in Greek, and imitating the band tied round the bottom of the original tree, as the plinth did the flat brick or stone on which it stood, to keep it from the ground. Between these two members was sometimes introduced a hollow channel, called *scotia*, from the Greek word for darkness, because little light could enter it.

The column was generally quite plain and smooth in its whole length; but in buildings where ornament was particularly admitted, the shaft was cut into a succession of small perpendicular channels, resembling the inside of a pipe or flute cut lengthwise into two parts; hence the shaft is called *fluted*. In some instances, one third part of the flutings from the bottom was, as it were, filled up with the half of a

* An anonymous writer on the history of architecture observes, that the art is supposed to have arrived at its glory in the time of Augustus Cæsar; but was, as well as other polite arts, neglected under Tiberius. Nero, indeed, notwithstanding his vices, retained an uncommon passion for architecture; but luxury and dissoluteness had a greater share in it than real magnificence. In the time of Trajan, Apollodotus excelled in the art, by which he obtained the favor of that prince, and erected that famous pillar called "Trajan's," which is remaining to this day. But after this time architecture began to decline, though it was for some time supported by the care and munificence of Alexander Severus; yet it fell with the western empire, and sunk into corruption. All the most beautiful monuments of antiquity were destroyed by the ravages of the Visigoths, and from that time architecture became so coarse and artless that these professed architects were totally ignorant of just designing, wherein the whole beauty of architecture consists; hence a new manner of architecture, called Gothic, took its rise. Charlemagne industriously labored for the restoration of architecture; and the French applied themselves to it with success, under the encouragement of Hugh Capet. His son Robert prosecuted the same design of modern architecture, and, by degrees, ran into as great an excess of delicacy as the Goths had before done of massiveness. To those we may add the Arabesques and Moresque or Moorish architecture, which were much of the same nature with the Gothic, except that as the former were brought from the north by the Goths and Vandals, the latter was brought from the south by the Moors and Saracens. The architects of the thirteenth, fourteenth, fifteenth, and sixteenth centuries, who had some knowledge of sculpture, seemed to make perfection consist wholly in the delicacy and multitude of ornaments which they lavishly bestowed on their buildings, but frequently without conduct or taste. In the two last centuries, the architects of Italy and France assiduously endeavored to retrieve the primitive simplicity and beauty of ancient architecture; nor did they fail of success, insomuch that now most churches, palaces, &c., are built entirely after the antique.

round rod lying in the hollow. It is singular, that the flutings may have been originally intended as an imitation of the natural hollows of the bark of a tree, and might therefore be expected in the earliest productions of architecture, it is only in the more improved works that fluted columns are to be found.

The *capital* is variously subdivided and ornamented in the different orders — simple in the Doric, more ornamented in the Ionic, and highly enriched in the Corinthian. In all, however, a narrow moulding runs through the shaft, near the upper end, called the *astragal*, because it seemed to occupy the position of the upper bone of the neck. Because the word astragal also means, in the Greek, the *heel*, it is, in some treatises on architecture, most ridiculously called by that name. The uppermost member of the capital is the *abacus*, so called, as being broad and thin, like the board or tablet employed by the ancients in arithmetical calculations.

The *volute* is an ornament introduced in the Ionic order, being, as its Latin word implies, a spiral scroll, imitating the ends of some flexible substance loosely rolled up.

The capital of the Corinthian order is encircled by rows of leaves of different sorts. The parts which rest upon, and are supported by, the columns, are comprehended under the general name of the *entablature*, because, agreeably to the meaning of the term *tabula*, in Latin, they consist of boards, planks, or stone slabs, of different forms and magnitudes. The entablature is a compound of three principal parts, first the architrave, next the frieze, and, uppermost, the cornice. The *architrave* is so called, by a name partly Greek and partly Latin, as being the *principal beam* which, resting on the capitals of the columns, supports the remaining parts of the entablature. In some cases it is plain, in others it is broken in two or three pieces, like so many separate beams lying on each other.

The *frieze* consists of one piece, but commonly enriched with sculpture of different sorts. In the Doric order, this ornament consists of two whole channels, and two half channels, forming one, if joined together, and therefore called by a Greek name *triglyphs*, or three hollows. The square spaces between the successive triglyphs are called *metopes*, a term expressing the hollow open spaces between the beams, the ends of which are represented by the triglyphs. In these metopes are sometimes represented the head of some divinity, the skull of some animal used in sacrifice, or other emblem of the purpose to which was destined the building on which the ornaments were introduced.

The *cornice*, from the French *corniche*, and the Latin *corona*, is so called because, being the uppermost part of the entablature, it *crowns* the whole architectural distribution of the columns; and it is divided and ornamented in different ways, according to the order employed.

1. The first Grecian order in point of antiquity is the *Doric*, so named from the *Dores*, a small tribe in Greece, or, as some say, from *Dorus*, an Achaian chief, who first employed that order in erecting a temple to Juno at Argos. In all the most perfect specimens of this order now remaining, the column springs immediately from the foundation, having no base properly so called, but only a small swelling round the bottom, resembling what we see at the root of a tree, and sufficient to show that we see the whole of the shaft. The base, we learn from Vitruvius, first appeared in the Ionic column. The Doric column being short in proportion to its diameter, and consequently strong, the entablature placed upon it, is, of course, more massive than that of the other orders, being in height one fourth part of the total height of the column.

2. The *Ionic* order derives its name from the *Iones*, a Greek people on the east coast of the Archipelago, whose capital was Ephesus, celebrated on many accounts, but particularly for the magnificent temple of Diana. This admirable structure was in length 425 feet, and in breadth 220 feet. It was surrounded on all sides by a double range of marble columns, 70 feet in height, and consequently 7 feet $9\frac{1}{2}$ inches in diameter at the bottom.

The Ionic column is taller than the Doric, containing 9 diameters, or 18 modules; and, although simple, is nevertheless graceful and majestic. If the Doric were meant to represent the manly, robust figure of Hercules, the Ionic might properly be the emblem of the dignified simplicity and elegance of Diana. In this order, as has been already observed, the base supporting the column was first introduced. An ornament peculiar to the Ionic column is the *volute* or spiral scroll already mentioned, which is described by a succession of portions of circles, drawn from different central points. The height of the whole entablature is $\frac{2}{6}$ of that of the column, being the medium between that of the Doric, which is $\frac{2}{8}$, and that of the Corinthian, which is $\frac{2}{10}$. The height of the base is one module, or half the diameter of the shaft.

3. The *Corinthian* order took its rise in the flourishing days of *Corinth*, a celebrated city, commanding the communication of the peninsula of Peloponnesus with the continent of Greece. The beautiful foliage of the capital of this order is traced back, according to Callimachus, to the following incident: A young lady of Corinth dying, her nurse carried her playthings in a basket, the day after her funeral, and placed it on the grave. The basket, covered with a flat tile, was placed accidentally on the stem of the plant *acanthus*, which, sending out leaves, soon enclosed the basket, having their ends turned downwards when they reached the tile. This object

struck the fancy of a celebrated sculptor of those days — *Callimachus*, who immediately introduced a figure of it on the top of an elegant column of his invention. Thus the capital of the Corinthian column always resembles a deep narrow basket covered with a tile, and completely surrounded by foliage. Such is the account given by Vitruvius; but later writers on architecture have imagined they could discover this ornamented capital in the description given of the temple erected by Solomon, in Jerusalem; with this difference, that there the foliage represented branches of the palm, and not the leaves of the acanthus. It is, however, to be observed, that the foliage of the Corinthian capital is frequently an imitation of the leaves, not of the acanthus, but of the olive, and of other plants, according to the taste of the architect. The Corinthian column is in height 10 diameters, or 20 modules, of which the base is 1 module and the capital $2\frac{1}{3}$ modules; consequently, the shaft measures $16\frac{2}{3}$ modules. The entablature is $\frac{1}{5}$ of the column.

1. The first *Italic* order is called the *Tuscan*, as having been employed by that ancient people, once very powerful in Italy. It is, however, remarkable that no vestiges now exist of any building in which the Tuscan column was employed to support an entablature, or any other weight. Vitruvius, it is true, gives instructions for erecting temples according to this order; but it does not appear that such edifices were actually erected. The only examples of the use of the Tuscan column that have come down to our times are the admirable monuments still subsisting in their original perfection, the column of Trajan and Antoninus in Rome, and the column of Theodosius in Constantinople. The column erected to the honor of Trajan, (next to Julius Cæsar perhaps the most valuable of the Roman emperors,) who flourished a century after Christ, is, in all, 118 feet high. The shaft of the column is in length $14\frac{1}{8}$ modules, or $7\frac{1}{4}$ diameters, each 11 feet 2 inches. The pedestal supporting the column is a cube of 3 modules; the base is 1 module, and the capital $\frac{2}{3}$ module. On the capital is another pedestal, on which stood a colossal statue of Trajan; but this was removed, and one of St. Peter now occupies the same place. The other column, commonly said to have been erected to Antoninus, is of the same kind, but a little smaller. It now supports the statue of St. Paul. The magnificent but unhappily situated column or monument erected in London to commemorate the dreadful conflagration which, in 1666, laid waste the greater part of that city, although copied from those in Rome, and of considerably larger dimensions, is not properly Tuscan, but a fluted Doric.

2. The other *Italic* order is called the *Composite*, because it seems to be a combination of the Ionic and the Corinthian orders, to which last it bears the greatest resemblance, imitating the former only in the adoption of the complete volute in the capital, in addition to the Corinthian foliage. A specimen of the Composite order, richly ornamented, is to be seen in the triumphal arch, of which are represented, in Scripture, the golden candlestick of seven branches, and other precious articles carried away from the last temple of Jerusalem.

Besides columns, properly so called, which are always circular, another kind of pillar, called *pilasters*, are frequently employed, especially where a great weight is to be supported. The plan of a pilaster is usually a square; but those, the plan of which is a parallelogram, are also introduced. The chief use of pilasters is to support arches. Thus the piers of a bridge are in fact short pilasters. The arches separating the nave from the side aisle of St. Paul's Church in London, and of St. Peter's in Rome, are supported on pilasters. In some buildings, it is true, we find ranges of arches supported on columns of even the delicate Corinthian order; but as columns are of a tapering form, the upper diameter being less than the lower, and as this diminution is increased in the eyes of the spectator by the distance of the upper part, the columns have a slender and even a feeble appearance, and consequently are ill adapted for supporting an arch. On the other hand, pilasters being of equal dimensions all over their height, and very short in proportion to their diameter, possess a solidity and strength capable of bearing arches of the greatest weight and magnitude. By pilasters we also mean an ornament applied to walls, internal and external, resembling in parts and form a column, but flattened instead of round. Pilasters of this sort have their base, shaft, and capital, and are plain or fluted, according to the architectural order to which they belong. It is a matter still unsettled whether such a pilaster ought to diminish in breadth, like a column, or to retain the same breadth above and below, like a solid pier. Pilasters usually project one fourth part of their breadth from the wall to which they are applied. Both columns and pilasters are frequently raised from the ground, and on pedestals — a construction not without its propriety in certain cases, as in our churches, where the galleries rest upon pilasters, and the front of the gallery coincides with the pedestal of the column which rises to the roof. Pedestals are by no means essential to columns or pilasters; but when employed, they must be formed and ornamented conformably to the order of the columns they support.

Columns are placed at different distances, according to their destination, and the spaces between them are termed *intercolumniations*. This separation in the Greek orders varies from one diameter and a half of the lower end of the column to four diameters; but if the Tuscan column were employed, the architrave being supposed to consist of beams of timber,

the intercolumniation may be much wider than if it consisted of blocks of stone. That interval, however, between columns, which has received the sanction of the best monuments of antiquity, and of the most judicious architects, is equal to two diameters and a quarter of the column. Hence it is called *Eustyle*, from two Greek terms expressing the proper arrangement of columns. The latter term, *stylos*, a column, enters into the composition of several other architectural terms, as pycnostyle, to express columns placed close together; prostyle, a number of columns placed as in a portico before the entrance, front of a building, of which we have examples in London, in the Churches of St. Martin-in-the-Fields, of St. George, Hanover Square, of St. George, Bloomsbury, in imitation of ancient edifices in Rome, &c. When ranges of columns are carried quite round the outside of a building, they form a peristyle.

Arches may, perhaps, be considered less magnificent than ranges of columns; but they are very solid, and liable to few accidents. The importance of arches in affording a commodious passage over a river needs no illustration. It has long been the practice to construct bridges of arches, increasing in width, and consequently in height, from each end to the middle, so that the road formed the segment of a large circle. The arches have also been generally semicircles. The practice was first laid aside in France, where many noble bridges are now to be seen, consisting, like the ancient Greek and Roman, of arches all of the same span or width, and the same height; so that the road is carried on a level all the way along the bridge. In order to keep the bridge low, the arches vary greatly from a semicircle, being segments of circles of large diameter. Nay, in some instances in France the arches are portions of ellipses, and not circular, by which measure the crown of the arch is kept very low. On this most improved plan a bridge is constructed in London over the Thames, between Blackfriars' and Westminster Bridges, which, for excellence of materials and structure, for magnificent simplicity and extent, is perhaps without a parallel in Europe. It consists indeed of only 9 equal elliptic arches; but each is of 120 feet span. The extent of each pier between the arches is 20 feet, and the length of the bridge 1280 feet, very nearly a quarter of a mile, on the same level line from one end to the other. To enable the reader to form some judgment of the properties of this work, (called the Strand Bridge, because it leads into that street, on the west side of Somerset Place,) the following account of some other remarkable bridges is given: Of the adjoining communications over the Thames, London Bridge consists of 19 arches, and is in length 915 feet; Blackfriars' Bridge consists of 9 arches, and is 995 feet long; and Westminster Bridge, consisting of 15 arches, is in length 1223 feet. The celebrated bridge over the Loire at Tours, in France, is horizontal, consisting of 15 elliptic arches, and in length 1335 feet. The bridge over the Moldaw at Prague, the capital of Bohemia, is in length 1700 feet. But these are all far surpassed in length by the antique bridge over the rapid Rhone, at St. Esprit, in the south part of France, which, constructed on a multitude of small arches, extends to the length of 3000 feet, possessing this singularity, that, instead of being straight, it consists of two lines of direction, meeting in the river at a very obtuse angle, pointed up against the stream, as if the better to resist its violence.

In various edifices, ancient and modern, we find columns and arches placed in ranges one above another. In such works care must be taken that the more massive are made to support the more slender, placing first the Doric order, next the Ionic, and, above all, the Corinthian or Composite. In this arrangement, the upper diameter of the superior column is usually made equal to the lower diameter of the inferior column, giving the succession of columns the air of one tall, tapering tree cut into so many separate portions.

The most remarkable edifices of antiquity which have subsisted with tolerable entireness to our days are temples of various sorts. The structure of these temples is extremely simple, the building being a parallelogram, seldom of great dimensions. Some have a portico of columns at the entrance, and the external walls plain or adorned with pilasters. Older temples, however, are surrounded on all parts by a single, and even by a double, range of columns, supporting the architrave, frieze, and cornice, together with the roof; so that the temple itself is in a manner concealed from the view, and receives no light but from the entrance. Such a construction is evidently very ill adapted to the purposes of a Christian, and especially of a Protestant, place of worship. It has nevertheless been imitated in many magnificent structures, with some alterations and the addition of projections in each of the long sides, for the purpose of resembling the cross, the emblem of the Christian faith. According to the system of divine service which for many centuries has prevailed in the Roman Catholic worship, the sacred offices may be conducted, without mutual interference, in sundry parts of the church at the same time. In the Protestant system, however, whether Lutheran, Calvinistic, or Anglican, in which nothing is done as it were in secret, and in which every member of the congregation is to hear and participate in every part of the service, sacred edifices must, to be useful, be limited in magnitude and form. To be satisfied of the truth of this observation, it will be quite sufficient to enter St. Paul's Church, in London, at a time when service is performing. A comparatively small portion of that grand structure is set apart for the congregation, while the great body of the building pre-

sents the appearance of a vast, useless void, neither applied, nor indeed applicable, to any purpose of the Protestant worship. The same observation belongs to the most ancient Gothic cathedrals; but these were constructed with a very different view.

The columns of the portico and pilasters of the body of St. Peter's, at Rome, reach at once from the ground to the attic; but in St. Paul's, at London, the whole of the edifice is divided into two ranges of columns and pilasters — an arrangement which, by breaking the whole into a repetition of small parts and members, counteracts the effect which would be produced by the great dimensions of the edifice were it adorned with columns occupying the whole height of the building. On the other hand, the intervals between the grand columns of the portico of St. Peter's having been built up into two stories of arcades and balconies, to accommodate the pope in certain ceremonies, the effect of the portico is destroyed; and, instead of one open range of lofty pillars, the eye is offended to see them half sunk, as it were, into a wall, the use of which is by no means at first sight apparent. From this material defect, the front of St. Paul's, although broken into two ranges of pillars, is fortunately free.

Columns grouped, or placed two and two together, have always a bad effect; for they suggest to the observer the idea that single columns have been at first employed, and, being found too weak for their load, another set of columns had been placed beside them to take off a part of the burden. Grouped or double columns are wholly a modern invention, nothing of the kind being found in any antique work; and although they were employed by the first-rate architects who constructed the celebrated colonnade of the palace of the Louvre, in Paris, the front portico of St. Paul's, the entrance into Somerset Place, in London, &c., the grouping of columns is, nevertheless, a departure from the genuine rules of the art.

Instead of different ranges of columns, it is usual to throw the ground floor of an edifice into the form of a basement, on which rise the columns or pilasters to ornament the front. This basement ought never to be less in height than half the length of the order it supports. Basements are generally rusticated; that is, the stones are cut and placed so as to resemble the rude blocks as they are supposed to rise from the quarry. In the application of this rustication, however, the judgment and taste of the architect will be displayed. In London, we have examples of the judicious employment of rusticated walls, and of the very reverse. The huge, ponderous masses apparently in all their native rudeness composing the exterior of Newgate prison, admirably indicate and characterize the nature of the edifice. The less rude, it is true, but still rusticated, walls of Carlton House are, on the contrary, equally incongruous with the delicate and richly-ornamented portico, and with the purposes to which that structure is appropriated.

When a building is divided into different floors, or stories, it seems proper that each story should have its separate range of columns or pilasters which then appear each to support the entablature and the projecting timbers of the superincumbent floors. When, on the contrary, two, and even three, tiers of windows are all included in the height of one range of columns or pilasters, the want of use, and even of connection, in columns of such a length, must strike every observer.

When a range of columns, surmounted with their proper entablature, supports the end of a roof, a triangular space is formed, called the *pediment*, the two inclined sides being finished agreeably to the cornice below them, the enclosed triangular space or tympanum is often filled with historic or emblematic sculpture. Pediments on a small scale, triangular or as arches of circles, are frequently placed alternately over windows in modern buildings; and instances of the same intermixture are not wanting in vestiges of ancient structures. The most proper proportion of a pediment, whether triangular or circular, is to make its perpendicular height from one fifth to one fourth part of the base.

The preceding observations belong to the Grecian and Roman systems of architecture; but another system, conducted on very different ideas, and of which many specimens of admirable contrivance and execution still adorn the principal states of Europe, namely, the *Gothic*, remains to be noticed. The term is often improperly employed to express every mode of construction not reducible to the ancient Grecian. In this way, works erected by the Saxons and the Normans in the northern and middle parts, and by the Saracens or Moors from Africa in the southern parts of Europe, are often confounded under the general name of Gothic with those to which that name properly belongs. This last species of building is supposed to have first appeared in England after the conquest, in the reign of Henry II., who died in 1189; introduced, most probably, from Normandy and other parts of France, where splendid monuments of Gothic architecture are very common.

On the origin of the Gothic mode of building, ingenious men have varied much in opinion, and even on the origin of the name. The Goths were in early times the inhabitants of Sweden; but in the decay of the Roman empire, they with other northern tribes invaded and even overrun all the southern parts of Europe, even to the Straits of Gibraltar. Ignorant of every art but that of war, the science and skill introduced into those parts by the Romans were overwhelmed, and architecture gradually assumed forms unknown to the Romans and the

Greeks. Hence, buildings constructed on principles different from those of antiquity came to be distinguished as Gothic, not because the Goths alone were their founders, but because the Goths and their neighbors the Vandals, having established a regular succession of kings in Spain, their name became more famous than that of any other northern race. The Saxon, Norman, and Gothic styles of architecture, though nearly related in sundry particulars, have still each its peculiar character.

The Saxon and Norman agree in this, that the form of the building is in both the same. The pillars are round, square, or polygonal, and very short, massive, and strong; but the arches and heads of the doors and windows are semicircular. If, in these particulars, any difference be found, it consists in the superior massiveness and large dimensions of the Norman architecture. The Saxon churches, of which sundry examples, or parts at least, have remained to our times, were often well constructed, and even elegant, but generally of moderate size. Those erected by the Normans, on the other hand, were usually large and magnificent, carried up to a great height, with two, and even three, ranges of pillars, one above the other, of various dimensions, but connected by circular arches. In the centre was a lofty tower, with two others at the west end, where was the principal entrance. In the course of time, however, the Normans introduced pillars of a much more agreeable form, tall and slender. In England, the Saxon and Norman styles are generally found mixed in the same building — the latter, introduced in the twelfth century, being ingrafted on the former, which had been in use for centuries preceding.

The principal marks by which the true Gothic architecture is distinguished are, its projecting buttresses around the exterior of the building, its pinnacles and spires, its large branching windows, its niches, its canopies and sculptured angels, saints, and kings, the fretted roof, the clustered pillar, but, above all, the arch, always more or less acutely pointed. As plainness and solidity constitute the leading features of the Saxon and Norman buildings, so the Gothic architecture is distinguished by the lightness of the work, the lofty boldness of its elevation, the peculiar slenderness of its pillars, the profuse and delicate richness of its ornaments, and, we must add, the astonishing excellence of the masonry.

In inquiries into the origin of the proper Gothic style of building, we meet with no less genius and fancy than in similar inquiries concerning the Greek orders, and much greater variety of sentiment. Some writers imagine the Gothic style was brought into England by the crusaders on their return from the Holy Land and other parts of the East, and think that this style should be called Saracenic. Others would call it Moresque, as having been introduced into Spain by the Moors. On the other hand, the pointed arch which characterizes the Gothic is, by some, traced to the intersection of two semicircles, such as is frequently seen in Saxon buildings — the one arch being described from the end of the diameter, and passing through the centre of the other. Such an intersection would form an angle of 60°, and lines from it to the other extremities of the arches would, of course, form an equilateral triangle — a form certainly not unfrequent in Gothic buildings. The scheme, however, which has gained the most general assent is, that the Gothic is derived from the ancient practice of religious ceremonies being performed in groves of lofty trees. The eye being accustomed to contemplate the arches formed by the branches of trees that shaded their altars and sheltered their assemblies, it was natural, when covered buildings succeeded to the groves as places of worship, that men should endeavor to introduce some similitude between them and those places in which they had been accustomed so long to perform their religious ceremonies. Accordingly, we find not only the intersecting arches formed by the branches exactly imitated by the pointed arch, but also the stems of the trees as accurately represented by the slender and clustering pillars of a Gothic cathedral. Indeed, no attentive observer ever viewed a regular avenue of well-grown trees intermixing their branches over head but it presently put him in mind of the long vista through a Gothic church, or ever entered one of the larger and more elegant edifices of this kind but it presented to his imagination an avenue of lofty trees intermingling their branches over his head. Under this idea of so extraordinary a species of architecture, all the irregular transgressions of art, all the monstrous offences against nature, as some men speak, disappear; every thing has its reason, every thing is in order, and an harmonious whole arises from the studious application of means proper and proportioned to the end. For, could the arches be otherwise than pointed where the workmen were to imitate the curve made by two opposite trees by their mutual insertion into one another? Could the columns be otherwise than split into distinct shafts, when they were to represent the stems of a clump of trees growing close together? On the same principles they formed the spreading ramifications of the stone work in the windows and the stained glass in the open interstices, — the one to represent the branches, and the other the leaves of an opening grove, — both concurring to preserve that gloomy light which, in the greater number of men, inspires religious awe and veneration. Hence we see the reason of their studied aversion to apparent solidity in these stupendous masses of building, deemed so absurd by men accustomed to the apparent as well as real strength of Grecian architecture; for the surprising lightness of the Gothic building, united with real

strength, was necessary to complete the execution of their original idea of a sylvan temple.

The origin of Gothic architecture here pointed out has been very happily illustrated and exemplified by Sir James Hall, in a dissertation published in the Transactions of the Royal Society of Edinburgh, and in a subsequent separate publication on the same curious subject, well worthy of attention.

In the architecture of the Greeks and Romans, the columns were admired for the elegance of their proportions; but in the Gothic, the column is seldom, if ever, diminished in diameter; nor do we find any fixed proportion between the diameter and the height of the column; nor is the intercolumniation or space between any two pillars regulated by the diameter of their height. Examples of the widest difference in the intercolumniations are common. For instance, in the nave of the Cathedral of York, and in the aisles of the conventual Church of Newark-upon-Trent, both edifices deservedly admired, but widely differing in the proportions of their columns and the intervals between them.

The Gothic column not being diminished above, and having no entablature, is the better suited, in point of stability, to support the arch springing immediately from it, as only a continuation of one half of the column. An arch springing from a Greek or Roman column has always, as was before observed, an unfavorable effect. The striking impression of a Gothic structure is produced by taking in the whole, in all its relations; but in the Greek architecture, our pleasure often arises from contemplating the elegance and fine proportions of its several parts.

On viewing a Gothic building, we soon perceive how admirably the parts are constructed for the eye to embrace the whole. The column is generally an assemblage of vertical mouldings, or a bundle of rods, enclosing a tall slender post or trunk of a tree acting as a conductor to the eye. The capitals present little or no interruption to the sight, which glides up along the pointed arch, and embraces the whole upper portion of the edifice. One of the vertical rods forming the column pierces through the capital, and ascends to the roof, and from it spring the ribs of the vaulting.

The exterior of a Gothic edifice has an effect similar to that of the interior. The vertical rods of the columns run up to the top of the pediment and the terminating pinnacle, and the pyramidal buttresses on the outside produce similar effects on the eye of the beholder.

GENERAL OBSERVATIONS ON THE CONSTRUCTION OF HOUSES.

In building, the situation is the first point to be determined. For dwellings, the position ought to be sufficiently elevated to be free from damps and noxious vapors, but, at the same time, not exposed to the wintry blasts. The neighborhood of fens, marshes, and stagnating waters should always be avoided; but water for domestic uses should always be easily and plentifully attainable. When a full southern aspect cannot be procured, the next best is a western; for the heat is always greater at equal distances from noon in the afternoon than in the morning. With respect to the ground to be built upon, it should be carefully examined by boring or sinking pits. Stone or gravel afford the best foundations; but if these be not of considerable thickness, dependence ought not, in all cases, to be placed upon such soils. If, however, it becomes necessary to found upon sandy, or upon marshy, boggy ground, the foundation must be secured by piling, planking, laying large ledges, or other contrivances of the same nature.

The situation being determined upon, the architect or builder prepares plans of the intended edifice, general and particular, with elevations of the fronts and ends, not drawn as they would appear to the eye of a spectator, agreeably to the rules of perspective, but according to their general dimensions as measured on a given scale. To the plans of each separate story must be added sections in length and breadth of the whole building, to show the elevation of the internal parts. As, however, no building can ever appear to the eye in the precise form of a geometrical elevation upon paper, and as it requires considerable skill and practice to be able, from such an elevation, to form a judgment of the appearance of the edifice when actually erected, it is most satisfactory, and, indeed, but just to the proprietor, to furnish him with views of the intended structure from different points of sight, accompanied by its attendant out-buildings, shrubbery, &c., such as they may be expected to be when brought to perfection. From the want of such general perspective representations, many a proprietor has beheld with disgust or mortification the completion of a residence on which vast sums were expended, and the architect has very unjustly been blamed; nay, in some cases ruined in his business, in consequence of such vexations and disappointments, occasioned by his unscientific employer. In cases of great public buildings, models of timber are often constructed, which, when done upon a properly adapted scale, convey a very perfect conception of the intended structures.

The external form, and the internal distribution of houses, are necessarily susceptible of such variety, that it is impossible to lay down any particular rules on these heads. A country seat is, of late years, usually arranged with a centre building for the family, and two wings, connected by covered passages with the centre, for various other purposes. The proportion that these wings should bear to the centre has never yet been ascertained; yet every passing

spectator will exclaim against the architect when the disproportion between the wings and the centre strikes him as extravagant. In some modern buildings of this nature we find the length of its wings in front, each only one third part of that of the centre; in others, one half; but nothing has a worse effect than disproportion between the body and the wings in point of height. The connecting passage or colonnade always looks best when it forms exactly a quarter of a circle.

The great difficulty in architecture is to combine utility with ornament and magnificence. This can, indeed, be properly done in structures of a certain extent alone; but even space and expense have not always been sufficient to insure these essential ends.

Excess of ornament is always misplaced in small buildings, which have then more the air of models of other great works than real places of abode. It was observed of Chiswick House, on the banks of the Thames, above London, (built in imitation, but on a small scale, of a noted structure of Palladio, near Vicenza, in the north of Italy,) that it was too large to hang to one's watch chain, and too small for a man to live in.

DOORS.

The size and proportion of doors must be regulated by the purposes of the building to which they belong. The door of a dwelling-house, corresponding to the human size, is confined to seven or eight feet in height, and three or four in breadth. In private houses, four feet may be the greatest breadth. In small doors, the breadth or width may be to the height as three to seven; but in large doors, as one to two. Doors intended to have but one leaf, or close, should never exceed three feet six inches in breadth, otherwise the door becomes too heavy for convenient use. Doors of a wider aperture, especially in the outer wall, are best formed with two folding leaves.

As to the modern fashion of opening a wide communication between rooms on the same floor, by means of broad folding doors, the practice sets all rules of proportion completely at defiance.

The external lintels of doors and windows should always be on the same level, and the doors should never be narrower than the windows. When the outward wall is ornamented with half columns and arches, forming blank arcades, the doors and windows should just rise up to the springing of the arches.

The most common way of ornamenting the aperture of a door is by an architrave on the top, and also down the sides. Sometimes a cornice and even a complete entablature may be placed above the lintel. Pilasters and semicolumns have also a good effect when applied to outer doors. Porticoes of four or more columns are properly adapted to large buildings.

WINDOWS.

The number and size of the windows of a building must be regulated by the nature and purposes of that building. The climate, the aspect, the extent, the elevation, even the thickness of the walls must be taken into consideration. When the walls are thick, which is commonly the case in detached stone buildings, the windows may have a considerable opening inwardly, which will admit nearly as much light as if the whole aperture in the wall were enlarged. The proportions of windows depend on their situation; only their width ought to be the same in every story — those in each, however, being proportioned in height to that of the apartments in each story. In the principal floor, the height of the windows may be two and one eighth to two and one third of the width. In the ground story, where the apartments are lower, the apertures of the windows seldom exceed a double square; that is, the height is just double the breadth. When the basement is rusticated, the height is generally much less. In the second floor, the height of the windows may be from one and a half to one and four fifths, or, rather, three fourths of the width. The window in the attics and mezzaninos or entresols may be a perfect square, or even lower.

The windows of the principal floor are the most enriched. The simplest ornament of such windows is an architrave carried round the aperture, with a frieze and cornice on the top. The windows of the ground floor are sometimes entirely plain; at other times they are surrounded with rustics or a regular architrave. Those of the second floor are generally closed with an architrave, crowned at times with a frieze and cornice; but these last ornaments would be improper in the attics. The breasts of all the windows on the same floor ought to be on the same level, and raised from two feet six inches to three feet above the floor. In warm climates, or in country houses in our own climates, seated amid gardens and pleasure grounds, the windows of the ground story being cut down to the floor, render the apartments pleasant and agreeable. In country houses, indeed, in France, Italy, and other warm parts of Europe, the principal apartments are all on the ground floor; and the other floors diminish in height as they rise above it. The windows of the ground floor being cut down even with the doors, and thus affording a ready communication with the garden or lawn, have a peculiar propriety. How far the same practice in the windows of the first and other floors, in the streets of large cities, by which the damps and cold of winter must inevitably penetrate into the apartments, ought to be avoided, is a point to be decided by those who prefer comfort and health to absurdities, however fashionable.

Not contented with adopting usages suited to

the genial temperature of the south of Europe, a stranger on passing along the new quarters of London might be tempted to imagine himself transported to the burning climates of India, when he beholds the fronts of the houses, whatever be their exposure, adorned, or, rather, loaded and blocked up, with vast projecting galleries, intended, but very unnaturally, to imitate the light, airy, and refreshing verandas of the East.

In so far as these galleries are on the *outside* of the windows and walls, they are certainly of use to intercept the immediate action of the sun's rays. On the same account, what we call Venetian blinds ought to be placed on the outside, and not on the inside, of our windows. On the inside, they keep off the glare of the sun's rays, but not the heat, which communicates to the air of the room, warming it just as much as if no blind intervened. On the outside, the blinds reflect and repel the heat as well as the light, and the air within the room preserves a desirable coolness of temperature.

The intervals of walls between windows should never be less than the aperture of the windows, nor in dwelling-houses greater than twice that aperture, otherwise the light will be deficient. The usual rule for proportioning the quantity of light to a room is, to multiply the length of the room by the breadth, and the product by the height. The square root of the last product gives the number of square feet of aperture requisite for properly lighting the room. Thus, suppose a room to be in length 32 feet 6 inches, in breadth 24 feet, and in height 15 feet; the product of these quantities multiplied successively into each other will be 1700; the square root of which, in even numbers, — 108, — will be the number of square feet of aperture required to lighten the room. This quantity, distributed among three windows, gives 36 square feet for each window; the width of each being 4 feet, the height must be twice and one fourth, or 9 feet. Had it been proper to open four windows in the same room, each must have contained only 27 square feet; and if the breadth of each were 3 feet 6 inches, the height would be 7 feet $8\frac{1}{2}$ inches. It is, however, to be observed, that both internal and external openings in houses, such as windows, doors, &c., ought always to consist of the uneven numbers, 1, 3, 5, 7, 9, &c., and never of the even numbers, 2, 4, 6, 8, 10, &c.

This rule cannot always, it is true, be observed in the confined spaces allotted to houses in towns; but in other situations, if the number of windows be even, the door cannot be opened in the centre of the building, and the want of an equal corresponding extent and balance on each side must strike the most careless spectator. The same rule is to be observed in distributing the arches of a bridge or an arcade, the intercolumniations of a portico or colonnade.

The proportions of rooms, in length, breadth, and height, are more the objects of taste and experience than of geometrical regulation. A circle or a square is a more perfect figure than an oval or a parallelogram; and a globe, a cylinder, or a cube, than a parallelopiped. A room, however, in the form of a cylinder or a cube, would, in general, be neither useful nor agreeable. The parallelopiped is, therefore, the form universally adopted for rooms or chambers of every sort, in which the greatest dimension is the length, the next is the breadth, and the smallest is the height. Some architects have made the breadth one half more than the height, and the length one half more than the breadth. Thus, for example, if the height of the room be 16 feet, the breadth will be 24 feet, and length 36 feet; and on the other hand, if the length be given, 22 feet 6 inches, the breadth will be two thirds of it, or 15 feet, and the height two thirds of the breadth, or 10 feet. Such a rule, however, must evidently be subject to many modifications.

The rooms on the ground or the second floor may be of the same length and breadth with those on the principal floor; but if they were of the same height, the impropriety would immediately strike and offend the eye. No defect in proportion, however, is more offensive than that in the height, and none takes more off from the appearance of a room. A low apartment, whatever be its other dimensions, never can possess either dignity or beauty.

It is the common remark of every one who, for the first time, enters the matchless fabric of St. Peter's, in Rome, that it by no means strikes the eye as so vast as it is known to be. This effect arises from the correct proportions of the whole edifice, in length, breadth, and height, and of the various members of which it consists. Had it been narrow, our attention would have been attracted to its great length. Had the ceiling been low, we should have been offended by its disproportionate length and breadth. Such, on the contrary, is the harmony of the several dimensions of the building, that no excess or defect in either of them leads us to institute a comparison between them. It is only by observing the time necessary merely to walk round and give a cursory glance to the interior of St. Peter's that the stranger can be convinced of its prodigious extent in all directions. Comparisons are seldom pleasing, and not always just; it would, therefore, be on many accounts unfair to compare St. Paul's of London with St. Peter's of Rome. It must, however, be acknowledged that the first view of the former has an effect very different from that produced by the latter, the chief cause of which is, that the nave of St. Paul's is really gloomy, and apparently narrow and low for its length; so that the spacious and lofty dome, instead of being only accessory, becomes the principal part of the edifice.

The proportions and dimensions of rooms must be regulated by their uses. A dining-room and a bed-chamber require very different proportions. A gallery for exercise in bad weather, especially if to be adorned with paintings and statues, must be of a length in proportion to its height and breadth, which last must be governed by the necessity of possessing light from windows on one side only, to exhibit with due advantage the paintings and sculpture ranged along the opposite side. A passage should be just wide enough to give a convenient communication between the several parts of the house; and if it be wider, we are offended with the waste of space which the architect ought to have turned to some other use.

There is no part of a building in which the taste of a builder can be better displayed than in the position and distribution of stairs. Even in the most spacious buildings, a step may be made too broad, so as to require a sort of effort to move up or down from one to another. In spacious stairs, the steps should vary from 12 to 18 inches in breadth, and from 4 to 7 inches in height; the length, also, varies from 6 to 15 feet. Even in small houses, a step over 7 or 8 inches high would be inconvenient; and the breadth should never be less than 9 inches, nor the length shorter than three feet.

We have thus given a pretty lengthy account of the theory of Architecture; and would now invite the attention of the student to the subjoined remarks on the practical branch of the science.

A competent knowledge of the methods of drawing on paper, and of working in stone, timber, or other materials, the several kinds or orders of columns, &c., is absolutely indispensable to enable the architect to discharge his duty to his employer, and the artisan to execute his commission.

It has been already mentioned, that an order of architecture consists of three principal parts, viz., the column, its pedestal, and its entablature. Each of these parts is again subdivided into three parts, thus: the pedestal into its base or lowest member; the cubical body, called from its figure the die or trunk; and the cornice above all. The column into the base, the shaft, and the capital. The entablature into the architrave, the frieze, and the cornice.

To give a minute, full, and perfect explanation of the proportions and manner of constructing these several members, with the various ornaments appertaining to each, would require an extent and a number of engravings totally incompatible with the design of the present work. Nor is this particular explanation deemed essential; for the number of publications on this head is already so numerous, that it is probable the student will find it more difficult to determine which to follow than to find a guide. Our observations will, therefore, be general and limited.

The simplest problem in mechanical architecture seems to be, to determine the best form for a column The length and the weight (that is, the quantity of materials in the column) being given, it is of importance to investigate the form which affords the greatest possible strength; but it is somewhat difficult to ascertain the precise nature and direction of all the forces to be resisted which act upon the column. If a column were considered only as a beam fixed in the ground, and acted upon by a force pressing transversely, or on one side, it ought to be much tapered, and reduced almost to a point at the upper end. But it is seldom that any force of this kind can be so powerful as to do more than overcome the weight of the column. The only thing, therefore, to be considered, is the load which presses on it from above; hence, whether we regard the force as tending to bend the column or to crush it, the forms commonly employed appear sufficiently eligible. Some mathematicians have erroneously recommended the cylinder as the strongest form to resist bending; and in this opinion, those who have not considered the subject are ready to join them, because a cylinder, standing perpendicularly on one end, being of equal thickness, seems also to be of equal strength throughout. From the principles of mechanical philosophy, however, it can be shown that the strongest form of an upright column approaches, in fact, much more nearly to that of an oblong spheroid or spindle of which the outside is an arch of an ellipsis. But the consideration of the flexure of a column is of the less practical importance in architecture, that, upon a rough estimate of the properties of the materials usually employed, a column of stone (in order to be capable of being bent by any weight which will not crush it) must be at least forty times as high as it is thick, although a bar of wood or of iron may be bent by a superincumbent load, if its length exceed about twelve times its thickness. But as, even in the Composite order, — the tallest and most delicate of all, — the height of the column is only, at the most, ten times the thickness at the base, the action of the incumbent weight, in bending the column, ceases to be an object of much consideration. It is only, then, as a crushing force that the weight requires to be estimated; and since the lower parts of the column itself have not only the weight above, but its own upper parts, to support, the thickness below ought to be somewhat increased. It appears, by experience of the direction in which the fracture of a column is made when crushed by too great a weight, that the outline ought to be made a little convex, or to swell a little on the outside of a straight line, joining the extremities of the shaft, and more curved above than below. This is the usual, but not the universal, practice. An elliptic arch is, perhaps, the most eligible outline, or a curve formed by bending a rule fixed at the summit of the column. It is very

natural, in forming a column, to copy the working of nature in forming the trunk of a tree, which may be considered, in a general sense, as a portion of a tapering cone, enclosed by straight lines joining the top and the bottom. But, independent of other considerations, it is to be remembered that the great load of the boughs, branches, and leaves act upon the trunk of the tree very differently from the load usually to be borne by a column. A light-house placed upon a rock in the sea may be considered as a column erected, not to support a weight, but to withstand the action of wind and water. If we calculated what would be the best form for a wooden pillar, intended to remain always immersed to a certain depth in water, we should find that a cone or a pyramid would possess the greatest possible strength for resisting the motion of water; and a cone still more acute than this would be equally capable of resisting the force of the wind, supposing it to be less powerful than that of the water. The part below the surface of the water might, therefore, be widened, so as to become a part of a more obtuse cone, the upper part remaining more slender; and the agitation of the sea being greatest at its surface, the basis of the pillar might be a little contracted, so as to have the outline of the lower part a little convex outwards, if the depth of water were considerable. But in the case of a building of stone, the strength often depends as much on the weight as on the cohesion of the materials; and the lateral adhesion, which is materially influenced by the weight, constitutes a very important part of the strength. For resisting a force tending to overset the building, the form in which the weight gives the greatest strength is that of a conoid; that is, a solid, of which the outline is a parabola, (a section of a cone parallel to its sides,) concave towards the axis, and convex outwardly; and for procuring, by means of the weight, a lateral adhesion every where proportional to the force, the form must be cylindrical. Hence, in a building such as this pillar is supposed to be, no reasons appear why either portion of its outline, taken separately, should be made convex towards the axis, although the joining of the two cones might very properly be rounded off. Of the form adopted for a building exposed to the violence of both water and wind, we have a remarkable example in the light-house erected on the Eddystone Rock, situated in the entrance of Plymouth Haven, about fourteen miles out from the land. The top of the rock on which the light-house is founded is, it is true, constantly above the surface of the water when the sea is calm; but in stormy weather, every part of the building is exposed to the action of the waves, the water being often thrown up to a height far above that of the light-house; so that it may be considered as exposed to the force of a fluid acting more and more forcibly as it is nearer to the foundation. On this account, the architect, the late ingenious Mr. Smeaton, chose for the walls a slope concave outwards, differing in form but little from that which the most accurate theory could have pointed out. The building, however, is probably a little weaker nearly as high as the middle of its height than in any other part. The light-house is wholly composed of cut stone, and about 16 feet in diameter at the bottom. The height of the building is 73 feet 6 inches from the rock to the top of the cornice; thence to the base of the lantern 7 feet 6 inches; and thence to the summit of the ball on the top 17 feet 6 inches; making the whole height 98 feet 6 inches.

In diminishing their columns, various rules seem to have been practised by the ancient architects. Sometimes the diminution began at the base, the shaft being formed by straight lines tending to a junction at a point beyond the summit of the column, by which measure the shaft became a frustum, or portion of a very acute cone. In other instances, we find the column carried up perfectly cylindric, or of the same diameter, for one fourth, or more commonly for one third of its height, at which points the diminution begins, and extends to the capital. This junction, however, of the cylinder and the cone, although the angle formed by their outlines be almost imperceptible to the eye, appearing an imperfection, it was proposed and practised by eminent architects to form the outline of the shaft, by a curve running within the cylinder, but without the cone, from the base to the capital, in such a way that the diameter of the shaft was, in every part, less than that at the base, but greater than that at the capital. The observations made on this point by Vitruvius, the great teacher of architectural mechanics, who flourished about the beginning of the Christian era, having in late times been misunderstood, it is no uncommon thing, in different parts of Europe, (to say nothing of our own country,) to meet with columns, the outlines of which consist of a curve, actually swelling outwards, so that at one third of their height their diameter considerably exceeds that at the base — a practice so offensive to the eye, as well as to reason, as to create wonder how it should ever be adopted by men who had ever seen, or even read, of the monuments remaining of ancient architecture.

The different methods of giving to columns the proper diminution and most elegant sweeping outline are particularly described in the body of this work. In this place, we must content ourselves with giving the following plain instructions, by which every practical artisan may form his model and plan with accuracy sufficient for ordinary occasions: —

Take the lower and upper diameter of the shaft of a column to be drawn. On the centre of the lower diameter describe a semicircle, and erect a

perpendicular to represent the axis of a column. Through the extremity of the upper diameter draw a line parallel to the axis of the column, cutting the semicircle at the base. Now, divide the arc of the semicircle made by the intersection of the last-mentioned line and the extremity of the base line into any number of equal parts, the more the better, as into 4, by points marked 1, 2, 3, &c. In the same way, divide the axis into the same number of equal parts, through each of which draw indefinite right lines, at right angles, to the axis. Through the points of the arc, at the base, draw lines parallel to the axis, producing them respectively until they meet the transverse lines drawn through on the axis, which will thus become points in the surface of the column. To assist in drawing these parallel perpendiculars, it will be convenient, through the points in the arc at the base, to draw lines to the axis parallel to the diameter, and setting off a distance equal to one of these lines upon the transverse line passing through the first line. Another, equal to that of the second, the points of the axis will be obtained as before. The setting on the transverses through the first point, a distance equal to the extreme points: in this manner, the points on the opposite side of the axis may be obtained. If, now, nails or pegs be fixed in the several points in the surface of the column thus ascertained, and along them and through the two extreme points of the upper and lower diameters a thin slip of timber, equally flexible in every part, be applied, it will show the contour or section of the exterior of the column. The curve thus formed, being carefully transferred, will mark the edge of the rule to be used in diminishing the shaft. In this process, it is evident that the more numerous the points of the surface ascertained, the more accurately will the slip of timber assume the proper form, and the diminishing scale be constructed.

MOULDINGS.

Although the shaft of a column may not admit of any ornament on its body, yet, at each end, in the base and the capital, various ornamental parts are introduced, in the due distribution and proportion of which consists their principal beauty. These are, in general, called *mouldings*, because they are always of the same shape, as if they all proceeded from the same mould or form. Mouldings are, by some writers, divided into Grecian and Roman, with a reference to the remains of the architecture of those nations still in existence. The difference consists in this—that the Romans generally employed circular arches in their ornaments, while the Greeks often introduced parts of an ellipsis, or of some other section of a cone varying from the circle. The principle parts of mouldings are these: 1st. The flat part under or above a moulding is a *fillet*, as resembling a bandage or turban tied round the column. 2d. When the moulding projects in the form of a quadrant or a smaller portion of a circle, it becomes an *echinus* or *Romano ovolo*, from its likeness to a portion of the shell of a sea-hedgehog or of a common egg. 3d. But if the moulding, reversing that figure, be a hollow of the same shape, it is, therefore, called a *cavetto*. 4th. A small projecting semicircular moulding is in general called a *bead*, as particularly belonging to the *astragal*, or neck; but, 5th. If the moulding be much larger, with a fillet above or below it, it then becomes a *torus*, as imitating a rope or cable applied to the column. 6th. If the section be a concave semicircle, or semiellipsis, it becomes a *scotia*, because the interior is dark. 7th. When the projection is not properly a part of a circle, but rather of an ellipsis, or of some other section of a cone, returning in quickly at the upper part, it is called a *Grecian ovolo;* and the quick return in it is by workmen called a *quirk*. 8th. A contour or section, partly concave and partly convex, is a *cymatium*, because it imitates the waves of the sea. 9th. If the concave part be uppermost, it is a *cyma recta;* but if the convex part be uppermost, it is a *cyma reversa*, or *ogee*.

VOLUTES.

A *volute* is a kind of spiral scroll, used in the Ionic and Composite capitals, of which it makes the principal characteristic and ornament. It has been called the *ram's horn*, from its figure, which bears a near resemblance to it. Most architects suppose that the ancients intended the volute to represent the bark of a tree, laid under the abacus, and twisted thus at each extreme, where it is at liberty. Others regard it as a sort of pillow or bolster laid between the abacus and echinus, to prevent the latter from being broken by the weight of the former and the entablature over it. Accordingly, they call it *pulvinus*. Others, after Vitruvius, contend that it is designed to represent the curls or tresses of a woman's hair.

The number of volutes in the Ionic order is four; in the Composite, eight. There are also eight angular volutes in the Corinthian capital, accompanied with eight other smaller ones, called *helices*. There are several diversities practised in the volute. In some the list or edge, throughout all the circumvolutions, is in the same line or plane. Such are the antique Ionic volutes, and those of Vignola. In others, the spires or circumvolutions fall back; in others, they project or stand out. Again: in some, the circumvolutions are oval; in others, the canal or one circumvolution is detached from the list of another by a vacuity or aperture. In others, the rind is parallel to the abacus, and springs out from behind the flowers of it. In others, it seems to spring out of the vase from behind the ovum, and rises to the abacus, as in most of the fine Composite capitals.

The volute is a part of great importance to the beauty of the column; hence architects have invented divers ways of delineating it. The principal are that of Vitruvius, which was long lost, and at last restored by Goldman, and that of Palladio.

DRAWING A COLUMN.

In drawing a column of any particular order, the several dimensions and members are measured by a proportional scale, founded on the diameter of the lower extremity of the shaft, immediately above the projection of the base, where the shaft becomes rectilineal. This diameter is divided into two equal parts, each being the radius of the transverse section of the column, and it is termed a *module*. The whole diameter is subdivided into sixty equal parts or *minutes*, of which, consequently, thirty are contained in a module. These proportional quantities are easily converted into real when the lower diameter of the column is given in measure. Thus, if the lower diameter of a Doric column be 5 feet, or 60 inches, the module must be $2\frac{1}{2}$ feet, or 30 inches, and each minute will be 1 inch; and the Doric column being in height 8 diameters, the height of the given column will be 40 feet: hence the entablature, being one fourth of the height of the column, its height in this case will be 10 feet, and so on.

In the Tuscan order, the height of the column is 7 times the lower diameter, or 14 modules; the entablature one fourth of the column, and pedestal one fifth of the height of all the parts. Hence, let the whole height of a Tuscan column, with its pedestal and entablature, be fixed at 40 feet, the pedestal, being one fifth of the whole, will be 8 feet high. The remaining 32 feet, divided by 5, will give nearly 6 feet 5 inches for the entablature, and 25 feet 7 inches for the column, of which the lower diameter, being one seventh, will be nearly 3 feet 8 inches. Had the order been Ionic, the whole height, 40 feet, divided as before by 5, (for, in all the orders, the pedestal is always one fifth of the entire height,) would have given 8 feet for the pedestal, and the remaining 32 feet, divided by 6, would have given 5 feet 4 inches for the entablature, leaving 25 feet 8 inches for the column, of which the ninth part, or 2 feet $11\frac{1}{2}$ inches, is the lower diameter. But, in general, when the whole height of the column, with its pedestal and entablature, is given, the several portions are thus found in all the orders. For the *Tuscan*, divide the entire height by 5; the quotient is the pedestal, and the remaining height, divided by 5, will give the entablature. The remainder, divided by 7, gives the lower diameter of the column. In the *Doric*, divide the whole height by 5, for the pedestal; one fifth of the remainder is the entablature, the rest is the column, of which the eighth part is the diameter. *Ionic* — deducting from the entire height one fifth for the pedestal, one sixth of the remaining height is the entablature, and one ninth of the remainder is the diameter of the column.

CORINTHIAN.

After cutting off the pedestal, as before, the entablature is one sixth of the remainder, as in the Ionic; and one tenth of the rest is the diameter of the column. For the *Composite* order, the same proportions are employed. In laying down any order on paper, draw a perpendicular right line to represent the axis of the column. Near the bottom, draw another line (horizontally) at right angles, on which, from the perpendicular, set off on each side a distance equal to a module, on one half the diameter. On a separate line equal to this diameter form a scale of sixty equal parts or minutes, by which to measure all the dimensions, reducing them to minutes from the number of feet and inches in which they are usually given. The construction of such scale is, however, generally unnecessary, from the variety to be found on Gunter's and other scales of wood, brass, &c., sold by the makers of mathematical instruments. On the axis of the column produced below it, set off, progressively downwards from the bottom of the column, the heights of the several members composing the base and pedestal; and through each of those points draw pencil lines at right angles to the axis. Again: from the same bottom line of the column set up along the axis the several heights of the capital, architrave, frieze, and cornice, drawing, as before, lines at right angles through each point thus ascertained. Then, from the axis, set off, on each horizontal line, the proper projection of all the several parts in order, by which means the true elevation and projection of each will be obtained. The extremities of these horizontal lines are then connected by the fillet, the ovolo, cyma recta, &c., according to the kind of ornamental profile belonging to each particular order of architecture.

The relative proportions of the various parts of the orders being accurately marked on the plates, any account of them here might be regarded as a work of supererogation.

A specimen of the Composite order, singularly rich and beautiful, exists at Rome, in the triumphal arch erected to commemorate the awful and predicted destruction brought upon the city and temple of Jerusalem by the Romans, in the year 70, under Titus, during the reign of his father Vespasian.*

* The remains of this triumphal arch stand very near the south-western limits of the ancient Forum. They are thus noticed by Theodore Dwight, Esq., in the Journal of his Tour in Italy: "It (the arch) is built with solidity, of large blocks of marble, in the form of a simple gateway; but the deep channels worn into its surface by time, and the immediate historical connection it has with the overthrow of Jerusalem, have imparted to it a moral grandeur which even superior antiquity or magnitude alone could never

Under the arch are sculptured the golden *candelabrum* of seven branches, the tables of showbread, and other spoils carried away from the temple. It is the ingenious, and not improbable, fancy of some eminent writers on architecture, that the general idea of the Composite order, as it appears in the Arch of Titus, was borrowed by some Roman artist in the suite of that general from the structure of the Temple of Jerusalem itself, after the conquest of the city, but before its final overthrow. Josephus, it is true, says the columns of the temple were Corinthian; but the differences between that order and the Composite might not attract his attention, nor would they have been generally deserving of notice. At any rate, the triumphal and tropheal Arch of Titus is the most ancient monument in which the Composite order is discovered. This arch possesses another peculiarity, that it is supposed to be the *first* structure of the tropheal or triumphal kind erected by the Romans — an example soon afterwards imitated by the abject adulation of the people, or, rather, by the insulting vanity of their princes, until at last such trophies, being lavished without discrimination, ceased to be marks of honorable distinction.

The feelings and duties of human beings in a social state of existence naturally spring from that state. To a person brought up from infancy in absolute solitude, such feelings would only produce misery, and such duties would be a nonentity. Let, however, two persons be placed in mutual communication, and that instant feelings of kindness or dislike, of affection or hatred, will arise. Let both be hungry, and let an apple or an orange only be procured; this each will instinctively desire to appropriate to himself, for an equal distribution of the object of their desires between them must be the result of posterior experience and reflection, and not the spontaneous suggestion of the occasion. If the one is a little stronger or more alert than the other, he will avail himself of these advantages over his fellow-being to seize the object of his wishes. By this sole appropriation, the other sustains not an imaginary, but a real, loss. The natural desire for necessary aliment will aggravate his feelings of disappointment and defeat into aversion, resentment, and revenge against his spoiler; and should he be frequently thwarted in a similar way by his companion, nothing short of the entire destruction of that companion will appear sufficient to secure himself from future privations and sufferings. This process will take place in the breast of the weaker being, even although the stronger should not attempt to assume to himself still greater advantages, in consequence of his acknowledged superiority. That the latter will, however, be governed by sentiments so moderate, is extremely improbable. The self-gratulation arising from consciousness of power will yield a flower too delicious not to induce the desire of again experiencing such delight. He will thus naturally be disposed to exercise his superior faculties, not when the calls of necessity only, but when the suggestions of vanity or caprice, may furnish opportunity. Hence, his feebler neighbor will, by degrees, be reduced to absolute slavery, dependent on the other for even the necessary means of existence; and of this existence itself, should he long continue refractory, he will probably be at last deprived. Thus may be traced the origin of the worst feelings and actions by which human beings are distinguished; and by a similar, but opposite, process, may the rise and progress of the best sentiments and conduct be explained. In absolute sequestration and solitude, neither virtue nor vice can exist; but without virtue and vice in society, human beings can have no existence. When this simple and obvious theory of what is called the origin of evil (a theory by far too simple and too obvious to have fixed the attention of presumptuous philosophy in any period of the world) is considered, it will excite no surprise that the history of mankind, under even the most favorable circumstances, should present little else than an endless chain of deplorable wickedness and wretchedness, equally the natural consequences of folly and vice. "We are a contemptible gang of plunderers, pests of society, meriting, forsooth, punishment the most severe and disgraceful, because we appropriate to ourselves the property of unoffending men, and even, on some occasions, deprive the owners of life; and all this we do, few in number, more frequently by secret stratagem than by open force, and even in some measure authorized by the sanction of necessity. Thou, on the other hand, born to independence, to wealth, to power, to supreme dominion, without even a rival to

possess. Those who have read the Scriptures from infancy, and been taught to mourn with the saints and prophets of Israel over the desolation of the city of David and the house of God, can never approach, unaffected, and regard this monument of heathen triumph. As we entered the shelter of the arch we trod the stones of the old Sacred Way, which lay yet undisturbed under our feet — probably the same pavement that Titus passed over in his triumphal march to the Capitol, when they brought the spoils of the Holy Temple and a large company of Jewish captives. On the right are seen, beautifully sculptured in relief, the seven golden candlesticks, the silver trumpet, the table of showbread, and the book of the law, all borne by priests marching in order; and on the other side is the emperor in his triumphal car, drawn by four horses harnessed abreast, and represented with the highest skill of the sculptor. The chariot is accompanied by the Genius of the Senate and Victory, bearing a crown of a branch of palm from Palestine. This record of history, containing more details than I have enumerated, still speaks to the eye and to the mind in language as clear and impressive as when it was first erected. But the unyielding spirit of the captives retains, to this day, all its pride and sternness. There are many Jews now in Rome, the descendants of the prisoners of Titus; but it is said that not a son of Israel has ever passed this detested spot, and trodden this part of the Sacred Way, since the day of his triumph. They still delight to trace back their pedigree to those whose humiliation they have inherited; while, it is said, not a man in being can establish a clear and undoubted claim to the blood of any ancient Roman family."

attempt to obstruct the gratification of thy desires, without provocation, without invitation, without necessity, without any motive or reason which a man of genuine courage and truth, a friend to human kind, would avow; thou destroyest cities, the abode of industry, knowledge, and patriotism; thou layest waste peaceable and flourishing countries, where thou hast received no injury; thou causest to flow torrents of the blood of nations who never even heard of thy name; and all this thou dost at the head of armed myriads, in open defiance of common justice and humanity; therefore art thou exalted to the rank of a hero, a conqueror of worlds, a demigod." In such a strain, we are told, was the mighty Alexander of Macedon addressed by the chief of a petty band of pirates who fell into his hands, and whom he conceived himself authorized to punish, in an exemplary manner, for their outrages on society; and the observations are fully warranted by the undeviating practice of all people and of all times. Hence, we find in the most ancient records of human society applause and reward lavishly bestowed on the successful warrior, whether just or unjust the cause in which he was engaged. But, beside this and other marks of the real or supposed admiration and gratitude of their armies and people, conquerors were in the habit of constructing some more substantial evidence of their victories on the scene of their exploits.

At one time a rude block of stone, at another a mould or hillock of stones and earth, raised on the field of battle, served at once to point out the spots where the honors of the victor were achieved, and where rested from their toils the human beings thus cut off in the performance of the duties he imposed. Of such monuments many examples still survive the long lapse of ages, in Great Britain — in Cornwall, in Wales, and in Scotland. These dumb memorials came at last into disrepute; they recorded, indeed, a slaughter and a victory; but succeeding generations, when tradition grew feeble or entirely died away, were left to conjecture the cause of their erection; and the mighty warrior was thus bereft of half his glory. When the Romans began to establish themselves in the southern parts of Gaul, and to extend the boundaries of their province, now Provence, Languedoc and Dauphiny, in France, they first constructed durable memorials of the success usually accompanying the exertions of united and well-disciplined bands, although far from numerous, against countless multitudes of irregular, ungovernable barbarians. Two Roman generals, Domitius Ænobarbus and Fabius Maximus, erected on the banks of the Rhone, *saxosæ turres*, towers built of stone, supporting trophies, consisting of arms offensive and defensive, standards, instruments of martial music, and other pledges of victory taken from the ancient Gauls. This conduct on the part of their commanders was highly reproved at Rome; for until then the Romans had never allowed themselves, even after their most signal success in war, to erect, in the midst of a conquered people, any monument whatever, by which they should be reminded of their subjection, and, consequently, be excited to endeavor to regain their former independence. "Never before this," says the historian, "did the Roman people upbraid any conquered nation with their own defeat." This happened about one hundred and twenty years before England's era. Some time afterwards, Pompey constructed, on the summit of the Pyrenees, near their eastern extremity, a permanent building, as a memorial of his successes, slight enough, indeed, over the partial but patriotic attempt of the Spaniards to throw off the Romish yoke. This action was severely reprobated at Rome. The same magnanimous sentiment actuated not the free states of Greece only, but even the despotic and military kingdom of Macedon. "States and nations," said those ancients, "like individuals and families, will differ upon particular points, where their interests, real or supposed, are concerned. These differences will lead to quarrels, and even to the most hostile proceedings and open warfare. It is not unnatural that, in these contests in arms, the victors should endeavor to confirm the courage and ardor of their own people, and to depress the spirit of their adversaries, by some public testimony of their superiority. For such a purpose, a few helmets, and breastplates, and shields, and swords, taken from the vanquished and supported against a spear, or suspended on a tree, on the scene of victory, will be fully sufficient: let not, however, such emblems of superiority be of long duration. The passions of men will cool, their views of interest will change, and the parties which to-day meet with deadly rancor in the field will be found in a short time united in one common cause, and fighting, as friends and brothers, against an ally of one of the parties on a former occasion, but now become a common foe. It is, besides, to be considered that success in war is not always attached to one side; no nation was ever always victorious, nor always discomfited. Let us never, therefore, by *permanent* records of our *temporary* superiority, labor to cherish and foment among our neighbors that spirit of hostility which, at no distant day, it may be equally our desire and our interest entirely to extinguish. Injuries men often will, and do, forgive; insults, perhaps, never." Such were the wise and magnanimous sentiments and principles of the Greeks and Romans, the two most enlightened nations of antiquity, in their best days. In the degenerate days of Titus and Vespasian, however, when Rome reigned paramount over the greater portion of the civilized world, the feeling of national importance and independence, the source and support of every manly, generous, and patriotic principle, was next to extinct in the nations of Europe. The example set in the case of Titus was speedily followed; and not only Rome itself, but

numbers of the principal cities over the empire, were adorned with edifices, triumphal, tropheal, and commemoratory, many of which still remain, exhibiting admirable specimens of architecture and sculpture, and, by the inscriptions and representations with which they are charged, serving to illustrate and establish the dates of many important historical facts. Wisdom, justice, and moderation are immutable; and, as such, never (let weak, and consequently narrow-minded, men say what they may) can be inexpedient or out of season. Human nature is, at this day, what it was twenty centuries ago. Let, then, the prudence and humanity by which states were then governed, and not the overbearing presumption and insolence on the one hand, and the abject, interested adulation on the other, by which later periods have often been characterized, suggest the most commendable models for modern imitation.

But to return to the Arch of Titus. It may be just to add, that the unfortunate branches of the Hebrew nation established in Rome made an arrangement, many years ago, with the government, agreeably to which, for the payment of a certain sum of money, they were permitted to open a narrow passage by the side of that arch, which, although not now connected with the inhabited part of the town, is situated in the heart of the old city, on a very public thoroughfare, that their minds might not be tortured unnecessarily by the display of the emblems of the final destruction and extinction of their religion and their state, of their name and their nation. This digression the reader will, it is trusted, without difficulty pardon. It arose naturally from the subject, and may, perhaps, suggest certain considerations not entirely unprofitable.

With respect to the kind and degree of ornaments to be introduced into a column and its appendages, it is a maxim, founded in our natural sentiment of what is decorous and beautiful, that if we are in doubt concerning the proper medium, we should always stop short of the proposed point, and be careful never to go beyond it. The pupil of an ancient painter in Greece produced a Venus loaded with jewels. "Unable to make the goddess beautiful," said his master, "you have thought to atone for that defect, by making her rich and fine." The dignified sobriety and gravity becoming an edifice appropriated to religious purposes or to the senatorial and legislative assemblies of a great and enlightened people; the massive solidity and strength inherent in our idea of a fortress; the light, airy, exhilarating notion attached to the name of a theatre or other places of amusement, — all these qualifications of the edifices to be constructed will, to an architect of genius, suggest the species and the measure of the ornament suitable to each. A slender, delicate, and highly-enriched Corinthian portico to Newgate prison could not be more incongruous, nor indicate a greater want of taste in the builder, than a massive, heavy, clumsy Doric (if Doric it be) range of pillars, and their pediments corresponding — apparently forbidding, but doubtless meaning to invite, the passing stranger to enter the theatre of Covent Garden. When we examine the monuments remaining from antiquity, we find that the cyma, the cavetto, or other ornament, formed by cutting into the substance of the work, is employed as a finishing only, and never where strength is required; that the ovolo and talon are employed to support the essential parts of the entablature, such as the modillions, dentils, and corona; that the principal use of the torus and astragal is to secure and strengthen the extremities of the columns, being also employed for the same purpose in pedestals, carved so as to resemble a rope or cable, agreeably to the original signification of the term *torus;* that the scotia serves merely to separate the members of the base, as does also the fillet, not only in the base, but in profiles of all kinds. By the term *profile*, is here meant the assemblage of parts, mouldings, and ornaments of a cornice, &c., in which the elevation and projection of each member are exhibited. The most perfect profiles are those consisting of the fewest mouldings, adapted to the order of the column, so disposed that the right lined and the curved members succeed one another alternately. In every profile one member should be predominant, to which all others must appear subordinate: thus, in a cornice, the corona is the chief member, the cyma of the cavetto covers and defends it from the rain, while the modillions, dentils, ovolo, and talon serve to support it. In the arrangement of the exterior of a building, whatever does not tend to characterize its destination, however beautiful in itself, is always misplaced. Greatness of character in an edifice is principally produced by largeness and simplicity of parts; such parts, not only by their own magnitude, but by the great masses of light and shade they exhibit when fully illuminated, excite the idea of grandeur. An object may be great, and not be grand; but grandeur and smallness of parts are incompatible. One of the most extensive edifices in Europe is the King of Spain's palace, at the Escurial, not far from Madrid. It covers a vast extent of ground, enclosing a number of courts, porticoes, chapels, &c., in its bosom. Having, however, been constructed as a monastery rather than as a palace, (for the royal apartments are confined to a very small portion of the structure, the building is divided into various floors, and consequently, the exterior walls are pierced with various ranges of comparatively small windows, adapted to the cells and halls of monks. The consequence of all this is, that the idea of grandeur and magnificence raised in the mind of the spectator, while approaching it from a distance and observing its prodigious dimensions, entirely vanishes away, when, on a closer view, the whole is discovered to be only an assemblage

of small diminutive parts and members, such as might be suitably introduced into a manufactory, a barrack, a hospital, or a convent. Many objections have been made to Blenheim Palace, in Oxfordshire, England, as clumsy, ponderous, inelegant, and by no means corresponding to the customary notion of a country residence. That magnificent edifice was erected, at the expense of the nation, to commemorate the signal victory obtained in 1704, near Blenheim, a village on the north bank of the Danube, by the allied army, under the Duke of Marlborough. That distinguished and modest commander stands, next to Julius Cæsar, unrivalled in history for perfect coolness and possession of himself in action; who, so far from ever exposing himself to the possibility of being surprised, whatever might have been the talents of his opponent, never rested until he was so close upon the enemy as, in many cases, to discover their measures, and prevent their forming any project against himself for the greater part of the campaign. Like Cæsar, also, in person a hero, he was scrupulously tender of the lives of his men, and, to spare them, would often forego the opportunity of a brilliant, but sanguinary and useless victory, for the more slow, but more secure and difficult advantages to be obtained by a skilful occupation of ground. On a due consideration of the destination of Blenheim, it will be manifest that the architect, Sir John Vanburg, intended, by throwing the structure into a variety of large, projecting, and retiring masses of building, to produce broad and powerful effects of light and shade, and by that contrivance to fill the spectator with the idea of the vast magnitude of the parts and of the whole far beyond what their real magnitude, considered as it is, could be expected to excite.

Besides regular columns and pilasters, we sometimes meet, in ancient and modern architecture, entablatures supported by human figures. These are termed *Caryatides*, from the following circumstance: Five hundred years before our era, Xerxes, the powerful monarch of Persia, led a prodigious army and fleet against the free and independent republics of Greece. Successful at first, more by treachery than by valor, he was at last discomfited at every point, and compelled to return in disgrace and ruin to his own country. Carya, a town of Peloponnesus, had basely formed a league with the invader; and upon his flight it was besieged by the other states, levelled to the ground, the male inhabitants put to the sword, and the unhappy, perhaps innocent, females reduced to slavery of the severest kind. To perpetuate to future ages the infamy and punishment of the people of Carya, in Athens, and in many other parts of Greece, buildings were erected, in which were introduced, in the place of columns and pilasters, figures of Caryan women supporting the load of a cornice and entablature. In general, these figures are attached, like pilasters, to the wall; but in Athens they are also found detached, and performing the duty of columns. Male figures are also employed in the same way in some ancient buildings in Greece and in Rome; in Greece, they are evidently intended to represent Persian prisoners taken from Xerxes. From this account, it is evident that human figures, in the place of columns or pilasters, ought, if at all, to be introduced on very particular occasions indeed. They nevertheless are often seen in the palaces of princes, and even in private dwellings. Our churches themselves, in which all adventitious distinctions among mankind ought, if any where, to disappear, are not free from this absurdity. These poor females, humiliated, borne down with a heavy load, are meant, we are to understand, for the Muses and the Graces, the Virtues, and the Angels themselves. Could the vices which corrupt, and the furies which torment, the human race be thus chained down, and so rendered in some sort subservient to our use, such an application of Persians and Caryatides might easily be reconciled to reason.

Not only entire human figures, but simple busts, are also employed, occasionally, to support the entablatures of monuments, chimney pieces, &c. The head is placed on a stand, smaller below than above; and the whole is called a *term*, from *terminus*, a boundary, the Roman name of the landmarks or march stones erected on fields and possessions to point out the boundaries between the lands of different proprietors. The protecting charge of these landmarks, as of every thing else connected with the affairs of industry and commerce, being intrusted to Mercury, by the Romans as well as the Greeks, the top of the stone or post was carved in resemblance of his head; so that to destroy, or remove, or deface such monuments was regarded not only as gross injustice to men, but as a voluntary and impious offence against the powers above.

It now remains to give a few observations on the constructions of bridges, one of the most important and difficult applications of architectural skill.

CONSTRUCTION OF BRIDGES.

By a bridge, we mean a structure of stone, brick, timber, or iron, erected over a river, a canal, a valley, or other depression in the ground; and supported on piers and arches, or on posts, for opening a communication for passengers, cattle, and carriages across from the one side to the other.

The perfection of a bridge consists in its having a good foundation, that it may be durable; of an easy ascent and descent, that it may be convenient; and of a just proportion in its several parts, that it may be beautiful. Bridges should always be placed at right angles to the course of the river, &c., and the piers should never be thicker than is just necessary

to support the structure against the force of the current.

The simplest theory of the arch supporting itself *in equilibrio* (that is, in such a state that the tendency of every part to fall down or give way is perfectly equal) is that of Dr. Hooke, the greatest of all philosophical mechanics, who flourished in the latter part of the seventeenth century. The arch, when it has only its own weight to bear, may be considered as the reverse of a chain suspended freely at each end; for the chain hangs in such a form that the weight in each link is held in equilibrio by the result of the two forces acting at its extremities. Two forces, or tensions, are produced, the one by the weight of the portion of the chain below any particular link, the other by the same weight, increased by that of the link, both of them acting originally in a vertical direction. Now, supposing the chain inverted so as to constitute an arch of the same form and weight, the relative situation of all the lines indicating the direction of the forces will remain the same, the forces acting only in contrary directions; so that they are compounded in a similar manner, and balance each other on the same conditions, but with this difference, that the equilibrium of the chain is stable, and that of the arch is tottering. When the links are supposed to be infinitely small, and the curvature of the chain is greatest in the middle, the chain forms what is called a *catenarian* curve, from *catena*, a chain. In common cases, this form of an arch differs but little from a circular arch of about one hundred and twenty degrees, or one third of a whole circle, rising from the abutments, with an inclination of thirty degrees to the perpendicular; the arch, however, becomes more curved at some distance below the summit, and then again less curved. The supposition, however, of an arch resisting a weight acting only in a vertical direction, is by no means perfectly applicable to cases usually occurring in practice. The pressure of loose stones and earth, moistened as they generally must be by rain, is exerted very nearly in the same manner as the pressure of fluids, which act equally in all directions; and even if the stones and earth were united in a solid mass, they would constitute a sort of wedge, and produce a pressure of a similar nature.

A bridge must also be so calculated as to support itself without being in danger of falling by the defect of the lateral adhesion of its parts. In order that it may, in this respect, be of equal strength throughout, the depth at each point must be proportional to the weight of the parts beyond it. This property belongs to the logarithmic curve alone, the length being made to correspond with the logarithm of the depth. But, in the construction of bridges, it is necessary to inquire what is the best form for supporting any weight which may occasionally be placed on the bridge; in particular, on its weakest part, which is usually the middle of the arch. Supposing the depth at the summit of the arch and at the abutments to be given, it may be considerably reduced in the intermediate parts, without impairing the strength; and whether the road along the bridge be horizontal or a little inclined, it is agreed that an elliptic arch, not differing much from a circular, is the best calculated for complying, as much as possible, with all necessary conditions.

The tier of bricks cut obliquely, which is placed over a door or window, is a real arch, but so flat as to allow the outline to appear horizontal. Little dependence, however, can be placed on so flat an arch, since it produces a lateral thrust, that might easily overpower the resistance of a side wall. For the horizontal force required to support each end of an arch is always equal to the weight of a quantity of the materials supported by its summit, supposed to be continued of their actual depth, to the length of the radius of the circle, of which the summit of the arch is a portion. This simple calculation will enable an architect to avoid such accidents as but too often happen to bridges for want of sufficient firmness in the abutments. Very eminent modern architects have sometimes been less successful in constructing arches of bridges and other edifices than those of former times, whom it is but too common to despise; and, for want of attention to mechanical principles, they have committed such errors in their attempts to procure an equilibrium as have been followed by the most mischievous consequences. Examples of this mismanagement might be pointed out in the bridges of our own country, and the churches of others; but if we are masters of the true nature and action of pressure, we shall be able to avoid similar errors, unless some defect in the materials, the foundation, &c., occur, which could not be foreseen.

It is desirable that the piers of bridges should be so firm as to be able not only to support the weight of half of each adjoining arch, but always to sustain the side thrust of one of them, should the other give way. The same condition is necessary for the stability of walls of any kind employed in supporting an arched or vaulted roof; hence the utility of the external buttresses, which strengthen and adorn Gothic structures. There are two ways in which a pier or a wall may give way; it may either be overset, or caused to slide away horizontally. But since the friction or adhesion which resists the side motion is usually greater than one third of the pressure, it seldom happens that the whole thrust of the arch is so oblique as not to produce a sufficient vertical pressure for securing the stability in this respect; and it is only necessary to make the pier heavy enough to resist the force which tends to overset it. It is not, however, the weight of the pier only, but that of half of the arch which rests on it, that resists

every effort to overset it; and, in order that the pier may stand, the sum of these weights acting on the end of a lever, equal to half the thickness of the pier, must be more than equivalent to the horizontal thrust acting on the whole height of the pier. The pier may also be considered simply as forming a continuation of the arch; and the stability will be preserved as long as the curve indicating the direction of the pressure remains within its substance. The dimensions of the piers must depend on the size and form of the arch, as also on the force of the current to be opposed. In tide rivers, the current acts twice a day in contrary directions, rising considerably above the surface of the river itself, and returning to that level. The pressure on the piers is, therefore, very unequal; and, from the circumstance that the stones must be thus in a continual alteration between wet and dry, the selection and placing of the materials becomes a matter of the greatest importance. Some persons are of opinion that blocks of stone resist the action of water and sun, of wet and dry weather, best, when placed exactly in the same position as when they lay in the quarry. Whether this circumstance, if real, was attended to or not in the construction of Blackfriar's Bridge, in London, or whether the stone was of an improper kind, it is certain that such parts of the piers as are exposed to be covered by the tide are now in a state of manifest decay, while the corresponding parts of Westminster Bridge are comparatively but little affected, although it was founded in 1738, and the former bridge not till 1760. The new Strand Bridge is built of granite, the least subject to decay of all stone from external causes. The stone employed in constructing the grand quay along the front of the arsenal of Woolwich, in England, was drawn from the vicinity of Dundee, in Scotland, and is found to answer much better in such a situation, where it is alternately, with short intervals, wet and dry, than any formerly employed. It has been likewise used in some of the great basins and docks in London, and in constructing the piers to support the iron bridge over the Thames, at Vauxhall.

In building a bridge, the most essential part of the enterprise is to secure a good foundation. The most simple method of doing this, and carrying up the piers to the ordinary height of the water, is to turn the river out of its course, above the position of the bridge, into a new channel opened for it, near the place where it makes an elbow or bend, or by raising an enclosure round the spot where the pier is to be built, to keep out the water, by driving a double row of piles into the bed of the river, very near one another, with their tops above the surface of the water. Hurdles are then put within this double row of piles, the side of the row which is next the intended pier is closed up, and the hollow between the rows filled with rushes and mud, so closely rammed down that water will not pass through. The mud, sand, stones, &c., within this enclosure, are dug out, until a solid foundation appears. When such a foundation cannot be found, one of wooden piles, having their lower ends well charred to prevent rotting, and driven into the bottom of the river as close together as possible, must be made. Some architects have formed a continued foundation the whole length of the bridge, and not merely under the piers. In doing this, first one part of the river is excluded, and then another, until the whole foundation be laid. When a river is but of moderate depth, having such a bed as may serve for a natural foundation, capable of bearing, without subsidence, in whole or in part, a heavy pier, then a strong frame of oak is constructed, and kept upon the surface by boats around it. On this frame is laid a thick stratum or layer of stone, cramped together by iron bars, and united by strong terras mortar, the whole of which, being then specifically heavier than the water, is suffered gently to sink down to the bottom, where the pier is to stand. If it be required to construct a bridge across a fordable river, or a canal, where the course of the water may be turned off, either by a wooden fence placed obliquely across the river or by a channel dug one side, then a dam must be formed entirely across the stream, with piles at a convenient distance above the place of the intended bridge. The ground is then dug out, until a proper solid foundation presents itself, and all the piers may be founded and raised up to the usual height of the river at the same time; after which, the river is permitted to return to its original channel. When the stream is by far too considerable to be turned aside, coffer dams are formed, of a circular shape, to enclose the spot where each pier is to be built. The dam is made, as before said, by driving into the bed of the river a double row of stout piles, either charred at the lower end, when the bed is easily penetrable, or shod for several feet with iron where it is hard. The piles are forced into the ground by repeated blows from the pile engine; the piles are covered with boarding, without and within, so as to be tolerably water tight; and the water which does make its way through the walls, or which springs out of the enclosed bed, is drawn off by pumps and hand labor, or, if the undertaking be considerable, by means of a steam engine.

Besides bridges, other bodies of masonry are also requisite, if not completely to transverse, at least to advance, a considerable way into the water. Such are the moles and piers carried out from the land into the sea, from opposite points of the shore, and mutually bending round towards each other at their extreme points, where they leave an interval sufficient for the passage of ships out or in. In our seas, where we have the advantage of the retreat of the sea twice a day, at low water such structures can be

founded and carried up, in general, without particular difficulty. In the Mediterranean, however, where the rise and fall of the tide is either very unimportant or wholly insensible, — as along the coasts of Spain, France, Italy, &c., — the construction of a mole becomes an enterprise of vast labor, difficulty, and expense.

The work begins at the shore, by throwing into the sea blocks of rock or stone, the larger the more useful. These find their place in the bottom, and, by accumulating block upon block over them, they at last rise above the surface of the water. The work being so far advanced, advantage is taken of the blocks above water to form a road, by which other blocks are carried out and rolled into the sea beyond those already placed, and these again in their turn serve, when they come to the surface, to convey another succession of blocks, until the foundation of the mole be carried out to the intended extent. When we take into consideration the inequalities of the bottom of the sea, where not covered with hard sand, the incessant internal motion of the waters, produced by currents, to say nothing of the superficial agitation produced by the winds, that most rocks and stones lose a great part of their weight when immersed in salt water, — and are, consequently, more easily moved about from place to place by the motion of the waters, — also the great extent in breadth to which rude blocks of stone or rock will necessarily roll before they find a bed, either in the bottom of the sea, or on one another, — when all these things are considered, the structure of moles and piers in such seas must appear to be an enterprise of extreme difficulty and expense. In such seas, however, no other mode of constructing an artificial harbor can be devised. When the foundation is supposed to be sufficiently consolidated, and is raised above the surface of the water, the mole is completed by a structure of hewn stone, founded in the interstices of the sunk blocks, adapted to the purposes of commercial and maritime affairs. Of this construction are the old and new models of Gibraltar, of Alicant, Tarragona, and Barcelona, in Spain; of Sette and Toulon, in France; of Genoa, Leghorn, Civita Vecchia, Naples, and Anchona, in Italy, &c. The famous antique mole at Pozzuoli, in the Bay of Naples, is constructed with piers and arches founded in the sea, and is, from its appearance, called Caligula's Bridge, having been, as is supposed, erected by that imperial monster. On the same principles with the moles just described is constructed what is called the Breakwater, in the entrance of Plymouth Haven, in England, in the view of abating the violence of the waves and currents which have, on many occasions, proved most prejudicial to the fleets resorting to that otherwise admirable station for shipping of every sort. In the report laid before the British Parliament concerning this prodigious enterprise, which was carried on at the public expense, the engineers, Messrs. Rennie and Whitby, (the former the engineer for the Strand Bridge, in London,) state that there are, properly speaking, three entrances into Plymouth Sound or Haven, viz., one on the west side of the bay, bounded by a long cluster of small rocks, called Scott's Ground, and the depth is only from 3 to 4 fathoms, (from 18 to 24 feet,) at low water; and on the east by the Knap and Panther, on which is about the same depth of water. This channel is about 500 fathoms wide, and the general depth is from $5\frac{1}{2}$ to 6 fathoms at low water. The middle channel is bounded by the Knap and Panther on the west, and by the Tinker and Shovel on the east; about 300 fathoms wide, and the general depth from $6\frac{1}{2}$ to 8 fathoms, at low water.

From this description, it appears that a large part of the middle of Plymouth Sound is shut up by the Shovel and St. Carlos's Rocks; that is, as a channel for large ships. Of course, works erected on those rocks would be no obstruction to a passage in or out of the Sound. If a pier or breakwater were constructed on the Shovel Rocks, and extended westward, so as to shut up in part the channel between them and the Panther, and also to shut up or narrow the spaces between St. Carlos's Rocks and Andurn Point, the tide being then confined to a narrow space, the velocity of the current would be increased, and, consequently, the channels where it passed. It seemed, therefore, proper that a pier or breakwater should be constructed in the Sound, having its eastern end about 60 fathoms east from St. Carlos's Rocks, and its western end about 300 fathoms west from the Shovel, forming, in the whole, a length of 850 fathoms. Of this pier, 500 fathoms in the middle should be straight, and 175 at each end inclined at an angle of 120 degrees. In addition to this breakwater, another should be extended from Andurn Point, on the shore, towards the former, of about 400 fathoms in length, having also a part inclined at an equal angle. These inclined parts were to repel the waves in such a manner as to prevent them from passing violently through the opening between the piers, and to shelter the Sound within, so as to permit fifty sail of line-of-battle ships to ride at anchor in safety, in all winds and weather, and with ample room to work their way out to sea, by one or other of the channels, as their position and state of the wind might render most convenient.

These great works were to be constructed by large blocks of stone thrown at random into the sea, in the line of the intended breakwater, to find their own bed. Stones from a ton and a half to two tons in weight would probably resist the swell of the Sound, in stormy weather. Where the water is five fathoms deep, the base of the breakwater should not be less than seven times that depth, or seventy yards in breadth, and ten yards broad, at a height of ten feet

above the level at low water or ordinary spring tides. The slope of this foundation on the outer side, next to the sea, should be in the proportion of three yards horizontal for one yard perpendicular; but the slope on the inside, next the Sound, would require an inclination of only half that quantity, or one and a half yards horizontal for one yard perpendicular. To the project here described (and now completed) various objections were made, particularly by Mr. Bentham, who had executed some works at Sheerness, at the conflux of the Thames and the Medway, somewhat of the same nature, but in circumstances incomparably more easy to manage than in the open, stormy entrance at Plymouth Sound. He observed that such a work as that proposed by Messrs. Rennie and Whitby, even supposing sufficient precaution to have been taken to prevent any injury to the harbor during its execution, and that the whole were completed in its greatest perfection, would, nevertheless, by opposing throughout its extent a complete interruption to the water, occasion such eddies in the wake of the work, and such an increased action on the bottom and sides of the parts left open, as could not fail of forming shoals, more or less injurious, according to the nature of the soil and other local circumstances. Mr. Bentham's plan was to sink in the sea, but in a line of direction different from that of the other engineers, a double row of cylindrical masses of stone work, leaving an interval between each two masses above equal to their diameter; placing the masses in one row opposite to, and covering the intervals between, the masses in the other row. By this arrangement, while the two rows in conjunction formed a complete obstacle to the direct course of the waves, the tide or current would be allowed to pass freely between the masses, throughout the whole extent of the breakwater; boats also, and even small vessels, might, in moderate weather, pass through the intervals without danger. Notwithstanding these objections and proposals, the scheme of Messrs. Rennie and Whitby, all circumstances duly balanced, was adopted by government, and ordered to be carried into effect. On a plan much of the kind proposed by Mr. Benham, was begun in France, before the revolution, a project for forming an artificial roadstead, or place of anchorage for ships of war, in front of Cherbourg, on the north coast of Normandy. This place, situated in the bottom of a wide, open bay, on a part of the coast projecting considerably into the British Channel, lies only about sixty miles south from the Isle of Wight, and, therefore, offers a most advantageous position for watching the motions of British fleets moving up and down the channel, or proceeding from or into the great place of rendezvous at Portsmouth or Spithead. Cherbourg possesses no natural qualifications for a shipping station, being merely a tide harbor formed by a small river falling into the sea. Basins have been excavated and locks constructed, in former times, by means of which frigates and smaller vessels could be conveniently protected; all with uncommon ingenuity, and at a very moderate expense. It was not enough for an engineer in France to give proof of his genius and skill in his profession, in producing the *best* method of accomplishing any desired object; his great merit consisted in inventing how to accomplish that object in the most *economical*, as well as the most *ingenious*, manner. By giving this turn to the public mind, works of the highest importance to the state and to individuals were carried on, in that country, for sums which, in some other countries, would be regarded as utterly inadequate to the purpose. All persons charged with the execution of public works, even those we call *civil* engineers, employed in the construction of harbors, bridges, canals, roads, &c., were military men, regularly bred, and under due but liberal control, enjoying rank and emolument sufficient for their station in society. An instance of a superior officer of the French corps of Royal Engineers suspected, accused, tried, and convicted of recommending works which he well knew to be unnecessary, not to say prejudicial, that he might have an opportunity of enriching himself during their execution; or of conniving at, not to say inventing, enormous abuses and extravagant expenditure, in the management of the public moneys, in order that he might be suffered, by the plunderers under him, quietly to amass his treasures; that a field officer of engineers should be proved to have stooped so low as even to make false returns of the quantity of coals and candles necessary for his official business, — an instance of such degrading delinquency is unknown in the history of French military jurisprudence. How far the same remark can be applied to another country, the constant rival, and often the enemy, of France, the records of the courts which take cognizance of such offences against duty, honor, and even common honesty, will bear ample but humiliating testimony. As Cherbourg possessed no outer harbor or road such as Portsmouth possesses at Spithead, it became necessary to enclose a portion of the bay to answer that purpose. Piers or breakwaters of continued construction were thought of; but at last it was resolved to sink a long range of wooden truncated cones into the sea at certain distances asunder, which, being afterwards filled with massy blocks of stone, would form a succession of solid, immovable masses, sufficient to break the violence of the external waves, and render the space within incomparably more quiet and secure than it was in its natural state. The cones were strongly compacted of oak, narrower above than below, and resembling a deep tub standing on its base, without a bottom. By most ingenious contrivances, the cones were floated out to their destined situations by means of empty casks, made air tight, which were afterwards

detached, and the frame allowed to sink to the bottom. The sides were of sufficient height to be always above water, and, when filled with stone, withstood the action of the tide and waves.

This great enterprise, the only thing of the kind in the world, was naturally interrupted by the disorders of the revolution in France, but was afterwards resumed with great activity, so that, in future wars with France, Cherbourg may become a most troublesome neighbor to Britain.

WOODEN BRIDGES.

Besides stone, timber is, on many occasions, employed to open a communication across a river; and in some cases it has greatly the advantage, as when the current is particularly rapid; for there the posts or piles supporting the road, presenting, either individually or collectively, but a small obstacle to the stream, often effectually resist its violence, when a stone pier, if it could easily be constructed in such a position, would not long keep its ground. Hence it is, that not only in England, but more particularly on the continent, stone bridges over great rivers are comparatively rare. Thus, on the Rhone, for instance, which, rising in the highest Alps of Switzerland, makes its way to the sea through the southern parts of France, bridges of stone have often been constructed, and as often carried away by the stream, so that at this day, perhaps, not more than two remain. The Rhone is, however, the most rapid river of its size in Europe. On the Rhine, which, rising not far from the source of the Rhone, takes an opposite course through Germany and Holland into the German Ocean, and is so much less rapid as its course is longer, stone bridges are quite unknown. But this is owing not only to the great body of water it carries along, but also to the policy of the different states along its banks, each unwilling that the opposite state should, by a standing bridge of masonry, possess means of making hostile attempts across the river. At Strasburg, for instance, a large and prosperous city of Alsace, in France, seated on the west bank of the Rhine, commanding by its fortifications a much frequented passage over the river into Germany, the bridge is formed by ranges of piles driven into the river to form the piers, supporting rafters and planks for the road, kept in their place by wooden bolts or treenails, so that, with a few strokes of a hammer or hatchet, the planks could be cast loose and removed, and all passage along the bridge effectually cut off. The German end of the bridge was also guarded by works to prevent the French from penetrating by that communication. This is the bridge of Kehl, celebrated in every history of hostilities between France and Germany.

Various are the methods employed in the construction of wooden bridges, governed principally by the extent of water they are to cross. Even in the narrowest it is improper to trust to the resistance of beams reaching from bank to bank, for they ought to be trussed; that is, to be supported by pieces of timber reaching from each bank, near the water, obliquely towards the middle of the bridge. This contrivance will add greatly to its strength, and prevent its bending under passing loads.

One of the most important particulars to be considered, in wooden bridges, is the seasoning of the timber. It is well known that the decay of fir timber is generally owing to the moist, sappy nature of its exterior surface. This moisture must be completely removed before any paint or priming be applied, in the view of securing it from the weather. If left in this natural state, this sap would, by the action of the wind and heat, be gradually carried off, and the fir beam become internally dry and solid; but if the surface be covered with paint, oil, pitch, or other substances of this kind, the sap is confined, and will soon corrupt the timber, which will give way before its time, and without any external symptom of decay. In order to dissipate the moisture or sap of the surface, it is sometimes the practice to scorch the timbers over a fire, turning it round regularly. The heat will attract the moisture to the surface and evaporate it, and the timber will acquire a hard crust, of great service in resisting the weather. When this is done, the parts that are to be under water should be carefully covered with pitch and tar, sprinkled with sand and powdered shells. Those which are in sight should, while the wood is still hot from the fire, be rubbed over with linseed oil, mixed with a little tar, which will then strike deep into the wood, and soon become so hard as to be fit to paint. Fir timber, thus prepared, is found to be nearly equal to oak in durability. At Schaffhausen, in the north part of Switzerland, was once to be seen a wooden bridge over the Rhine, there very rapid, so that no stone bridge could resist it—admirable in its construction, and being the production of a plain country carpenter. The builder was directed to avail himself of a part of one of the piers of the stone bridge still remaining in its place, to support the intended structure. With this order he apparently complied, but so contrived matters that, in the opinion of the best judges, his bridge actually consisted of but one immense arch, of near four hundred feet, (the breadth of the river,) having a part stooping down, as it were, to rest upon the pier in the water, but not, as far as could be discovered, actually resting on it. With very long fir beams, prepared for the purpose, extended at an angle of moderate elevation above the horizon from both sides of the river, and in conjunction with intermediate timbers, meeting over the water, two arches were formed, being segments of large circles, and resembling the circular frame of the centring of a stone bridge. These arches were placed parallel to one another,

at a distance sufficient for the breadth of the road, which was formed upon timbers suspended from the arches on each side, so as to be quite horizontal from end to end; and, instead of going over the supporting arches, was, in fact, let down between them. The whole was roofed over, and enclosed at the sides, with windows at convenient distances to defend the timber from the weather. This most ingenious and most useful piece of carpentry, which had gained the applause of all men of genius and skill, completely answered its destination from 1740, when it was constructed, to 1799, when it was destroyed by the French.

IRON BRIDGES.

Bridges of iron are the production of British ingenuity exclusively. Iron being the great staple metal of the country, it has of late been employed in many works where great strength is required in proportion to the weight of the materials. Melted or cast iron possesses several advantages over stone or wood; and these, in their turn, possess advantages over cast iron. To stone, iron is superior in tenacity and elasticity, and thence in strength, in facility of formation in any desired shape, and in extent of the masses in which it may be formed — qualities all conducing to its superior lightness and cheapness. To wood, iron is superior in the same particulars, together with durability; but in this last respect, stone has greatly the advantage over iron equally exposed to the weather or other natural agents. The greater durability of stone arises from its being less liable to decomposition from the atmosphere, and from its being less elastic, and consequently less subject to friction among its component particles, in yielding to the load and motion of carriages passing over it. Several ways may, however, be adopted to remedy, in a great degree, these defects of iron. Paint will prevent it from oxidation, or rusting, for many years, and the application may, when necessary, be repeated without much expense. Cast-iron carriages of garrison guns have, by various external applications, been perfectly preserved for upwards of a century. The vibratory motion of an iron bridge may also be considerably diminished by the manner of placing and connecting the bars of which it consists, so that each bar shall act as nearly as possible at right angles against another, and be at the same time so short as not to be in danger of being bent or crushed by the pressure against its length. The greatest objection in this respect to cast iron is this — that, on account of the imperceptible differences in the purity and other qualities of the metal, it is impossible to cast two bars or blocks even in the same mould, which shall shrink perfectly and equally in cooling, and, consequently, be of precisely the same dimensions when employed in the work. When such pieces come to be joined together, therefore, some empty space must necessarily exist among them, which in a large work, where many pieces are employed, must produce a very sensible play in the joinings, and, consequently, great vibration or reciprocal motion in the whole structure. This inaccuracy of the joinings may, it is true, be in some measure corrected, by inserting pieces of sheet lead in the joinings; but this metal possesses by far too little cohesion of parts, and too little elasticity, to be of use for any length of time. In order to prevent the evils arising from these defects of cast iron, it has been proposed to fill up the vacant spaces left between the iron framing with some compact, cheap materials, such as brick united with the composition called Roman or Parke's cement, or Pozzolano, or terras, which would readily and intimately combine with the iron, thus defending it from the action of the atmosphere. The interstices between the bars being thus also filled up by a consolidated substance, the play, friction, and vibratory motion of the bridge would be greatly diminished. Lightness being, however, a most desirable property, it has also been proposed to form hollow bricks solely for this purpose, which, being carefully and thoroughly baked, or even semi-vitrified on the surface, would be proof against the effects of the atmosphere. In many parts, bricks are still seen in remains of Roman buildings, fifteen or sixteen hundred years old in perfect preservation, while the stones, with which the bricks are built up in alternate layers, are often greatly decayed, unless when enveloped in the admirably-constituted mortar of those days. Iron may be used for bridges, either on the principle of equilibration, as stone is employed, or on that of connection by framing, as wood is sometimes employed in bridges, but generally in roofing houses. For bridges of considerable dimensions the former is, by many judges, esteemed the best mode; but for small bridges, the latter mode will probably be found the cheapest. As iron bars, rods, or blocks may be firmly connected together by bolts, or other means, an iron arch may be constructed much flatter; that is, in the segment of a much greater circle than if it were of stone — an advantage of very great importance in certain positions, where arches of great span are required. The first iron bridge of any note constructed in England was that of Colebrookdale, in Shropshire. It consists of five ribs, each of three concentric arches, bound together by pieces in the direction of radii of the circle. The interior arch forms a semicircle, but the others reach only to sills under the road way. These arcs pass through an upright frame of iron at each end, serving as a guide; and the small space in the haunches, between the frames and outer arc, is filled up with a large iron ring. On the ribs are laid cast-iron plates, to support the road. The span, or opening of the arch, is 100 feet 6 inches, and the height from the base line to the centre is 40 feet. The road along the bridge is 24

feet broad, formed on a bed of clay and iron slag, (the refuse from the furnace where iron ore is smelted,) a foot in depth.

Another bridge of the same material was afterwards erected over the mouth of the River Were, forming the Harbor of Sunderland, a great coal port in the county of Durham. The peculiar construction of this bridge consisted in applying iron, or other metallic substance or compound, to form arches on the same principle with stone arches, by a subdivision into blocks easily portable, answering to the keystones of a common arch, which, being made to bear on one another, will have all the firmness of a stone arch. At the same time, by the great open spaces left between the blocks and their respective lateral distances, the arch becomes materially lighter than if it were of solid stone, and, by the tenacity of the metal, the parts are so intimately connected that the delicate but indispensable calculation of the size and weight of the stones composing the arch becomes of but little importance. This bridge is in span 236 feet, and as the stones from which the arch springs on each side project 2 feet, the whole opening is 240 feet. The arch is a segment of a circle of 222 feet radius, and the height from the chord to the top of the arch is 34 feet; but the whole height of the middle of the arch above the surface of the river, at low water, is about 100 feet, so that ships can pass under it. A series of 105 blocks form one rib, and six of such ribs compose the width of the bridge. The vacant spaces between the arch and the road are filled up by cast-iron circles, which touch the outer circumference of the arch, and also support the road, gradually diminishing from the abutments towards the centre of the bridge. Diagonal iron bars are laid on the top of the ribs, reaching to the abutments, to keep the ribs from twisting. The superstructure is a strong frame of timber, planked over to support the carriage road, composed of marble, limestone, and gravel, with a cement of tar and chalk laid on the planks in order to preserve them. The whole width of the bridge is 32 feet. The abutments are masses almost of solid masonry, 24 feet in thickness, 42 in breadth at the bottom, and 37 at the top. The weight of the iron in the whole work is 260 tons, of which 214 are cast, and 42 wrought iron. The expense of the whole, forty years ago, was £27,000, or $119,880. The Waterloo Bridge, over the Thames, will be illustrated by a plate for that purpose.

BRIDGES IN BOSTON.

Some of the most striking objects which attract the notice of strangers on visiting Boston, Massachusetts, are the bridges which lead from its various points. Although we cannot boast of so grand superstructures as the ancient city of London, we, nevertheless, have a greater number of those convenient avenues. The Western Avenue is a splendid mill dam, built of solid materials. Warren Bridge was built in 1828. All these bridges are well lighted by lamps when the evenings are dark; and the lights, placed at regular distances, have a splendid and romantic appearance.

WESTERN AVENUE.

This splendid work was projected by Mr. Uriah Cotting, who, with others associated, received an act of incorporation, June, 1814, under the title of "The Boston and Roxbury Mill Corporation." It was commenced in 1818, under Mr. Cotting's direction, but he did not live to witness its completion. His place was supplied by Colonel Loammi Baldwin, and the road was opened for passengers July 2, 1821. This Avenue, or Mill Dam, leads from Beacon Street, in Boston, to Sewall's Point, in Brookline, and is composed of solid materials, water-tight, with a gravelled surface, raised three or four feet above high-water mark. It is one mile and a half in length, and a part of the way 100 feet in width. The water which is admitted is rendered subservient and manageable. Very extensive mill privileges are gained by the aid of a cross dam, running from the principal one to a point of land in Roxbury, which divides the *reservoir* or full basin on the west from the running or empty basin on the east. There are five pairs of floodgates in the long dam, grooved in massy piers of hewn stone; each pair moves from their opposite pivots towards the centre of the aperture on a horizontal platform of stone, until they close in an obtuse angle, on a projected line cut on the platform, from the pivots in the piers to the centre of the space, with their angular points towards the open or unenclosed part of the bay, to shut against the flow of tide, and prevent the passage of water into the empty basin. In this manner, all the water is kept out from this basin, except what is necessary to pass from the full basin through the cross dam, to keep the mill works in operation. The reservoir is kept full by means of similar floodgates opening into the full basin, (when the rising of the tide gets ascendency over the water in the reservoir,) and fills at every flow, and closes again on the receding of the tide. In this way, at every high tide, the reservoir is filled, and a continual supply of water is made to pass through the sluice ways in the cross dam, sufficient to keep in motion, at all times, at least one hundred mills or factories. At low water, the floodgates of the receiving basin open and discharge the water received from the reservoir.

WARREN BRIDGE.

The construction of this bridge was commenced in June, 1828, and was completed in November following, under the superintendence of Joshua Burr, Esq.,

of Charlestown, Massachusetts. It is one of the most perfect works of its kind in the Commonwealth. It is certainly not exceeded by any other in point of durability and ease of travel. It opens on the Charlestown side, about ten rods above (west) Charles River Bridge, and, running in a southerly direction, terminates on the westerly part of the Mill Pond Land, so called, in Boston, just east of the Middlesex Canal. It is the most direct, and the shortest, communication between Boston and Charlestown.

The bridge is supported by 75 piers, placed at equal distances of 18 feet. It is 1390 feet in length, and 44 in width, allowing 30 feet for the carriage way, and $6\frac{1}{2}$ on either side, handsomely railed, for foot passengers. The floor of the bridge is composed of hewn hemlock timber, about 14 inches deep, the apertures between which are well chinked with small pieces of stone, the whole covered with 6 inches of tempered clay. On this is spread 8 inches of coarse gravel, covered with 8 inches of macadamized stone. The sides of the carriage way are secured by edge stones, 12 inches deep and 9 thick. The floor timbers are placed lower than those of other bridges, in order that they may be occasionally wet by the high tides, which, it is thought, will tend to their preservation. That teams pass over this bridge with great ease is sufficiently demonstrated by the fact that a single yoke of oxen has been known to convey $16\frac{1}{2}$ tons at one time, from the draw into Charlestown, without any unusual effort.

The draw, in the centre of the bridge, is of sufficient width to admit vessels of three hundred tons. It has wharves on each side, built on piers which are planked from the capsill to low-water mark, for the more safe and easy passage of vessels. Its conveniences, in this particular, are in strict agreement with the general excellence of the whole structure.*

TOWN'S IMPROVED BRIDGES.

A minute and accurate description of Town's improvement in the construction of wooden and iron bridges is given in a succeeding part of this work. We commend the article to the learner, as being particularly worthy of his serious and attentive consideration.

WHITE'S TUBULAR SUSPENSION BRIDGE.

[Patent Right secured.]

Ammi White, Esq., of Boston, has a model of a bridge, which supersedes the necessity of piers in crossing our largest rivers. He asserts that it can with safety be extended, even for railroad purposes, fifteen hundred feet. The mode of its construction is as follows: —

"First, erect the towers on good and firm abutments, or on a rocky bank; then extend across the stream two or more sets of stringers, according to the number of road beds needed. The number of stringers in each set will depend upon the amount of strength required in the bridge. Each stringer is made by selecting a tree of proper size, which is sawed square, and is tapered from the top to within about five feet of the base. This serves as a starting-point, on which are spliced good sound boards, six or seven inches in width, on a curve of forty feet in five hundred, till the required length and thickness is obtained, the whole terminating in a corresponding timber which forms the other extremity. In securing one board upon another, care is taken to fix keys of wood or iron into mortises made half into one board, and half into the other, to prevent the stringer from elongating, which, with the additional bolts placed near the dowels, is as incapable of divulsion as the

* This bridge was considered, at the time it was built, to be a very durable and scientific structure; but, in 1840, it was found to be in so decayed a state that immediate repairs were necessary to render it in any degree safe for travel: a thorough examination was made, which resulted in a recommendation to remove the clay and stones referred to, and make such other alterations as the case might demand.

In the Bay State Democrat of October 8, 1842, we find the following description of the repairs made at that time: —

"Warren Bridge has recently been thoroughly repaired in all its parts. All the old timbers have been removed, and new materials substituted. This work has been done under the direct superintendence of Ebenezer Barker, Esq., the agent of Warren Bridge, who has completed it in a manner highly creditable to himself, and worthy of the magnitude of the enterprise. It is a fine specimen of mechanical skill, is somewhat novel in its style of execution, and may be looked upon as one of the greatest works of its kind in the country. We have thought that some statistics in connection with this subject would not prove uninteresting to the general reader.

"Warren Bridge was incorporated March 12, 1828, and opened in the subsequent December. It is now 1388 feet in length, of which 1318 feet are covered by hexagonal blocks of white pine. Its whole width is 44 feet — the travel way being 30 feet, and the side walks occupying 7 feet each. To begin at the foundation of the work, and for the purpose of giving the public accurate information of its whole construction, we will say, first, that on the heads of the piles white pine caps, 14 inches square, are placed; on these caps rest stringers 6 by 14 inches, of the same material, in a longitudinal direction, being on the outside 12 inches deep; thus making in the centre a crown of two inches elevation. On these stringers, transversely or at right angles, rest yellow N. C. pine ribbons, or laths, 4 by 5 inches, and spiked to every other stringer by 8 inch spikes. Upon the end of these ribbons, and over the outside stringer of the road way, white pine edge timber, 10 by $6\frac{3}{4}$ inches, is laid so as to project 2 inches each way beyond the stringer beneath it. This timber is bolted to the stringers once in every 4 feet, to secure more firmly the ends of the ribbons in their places; and on the under side of these timbers, and about one inch from each edge, grooves of half an inch deep and wide are made.

"On such a foundation as this, the white pine blocks — which, by the way, are of Maine pine, and have been alluded to — are laid. As a matter of experiment, blocks of 10 and 11 inches size are put down on the Boston side, and of 12 inch size on the Charlestown side. These blocks are all tongued and grooved, or matched, which serves to secure the whole firmly together, and to present an even and uniform surface. On the surface of these blocks is put a liquid preparation — first, a coat of turpentine mixed with oil, then a coat of tar and pitch poured on very hot. To this is added a coat of gravel, rolled in by a machine, so as to fill the interstices and pores of the blocks. The object of all this care is to preserve the material

tree itself. This suspension chain or stringer is run across the stream by means of a wire cable and pulleys, and when locked and keyed fast in the towers, with the two backstays, is allowed to take a catenary curve. After a sufficient number has been extended across, the suspension rods are bolted to them and to the girders, which are made slightly arching, and to the floor joist. The rafter is connected with the stringer and top of the suspension rod, to which is bolted the roof, constructed of double diagonal boarding. The floor, if a turnpike bridge, made of double diagonal planking, bolted together, is then laid, and, in the capacity of cross bracing, serves to render firm the whole structure. If a railroad bridge, the cross bracing is fitted under the floor joist, in connection with the girders. By loading either kind of bridge with double the weight it is required to sustain, the girders will be brought down to a level, and, while the weight is on, the sides are covered with a double-diagonal boarding, similar to that of the roof, both of which must be firmly attached to the towers and backstays to form a part of the strength of the bridge. The direct arches are formed by bolting together planks on the right curve. One springs from the abutment, and connects with the stringer at the top of the suspension rod; the other starts from the same point, and connects with the other girder, both connecting in their course with the suspension rods. The side guards, or braces, are formed by fitting a fender rave to the floor joist, which extends over the girder several feet, according to the length of the bridge. Short rafters connect with the fender rave and the suspension rod. These, together with the projecting floor joists, are covered with double diagonal boarding. These braces prevent the bridge from vibrating. The backstays connected with the studs inserted in the sills of the towers extend back on shore the required distance, and are firmly attached to stone posts, deeply set in the ground at the extremity of the sills."

[As regards the strength, economy, durability, and safety of this bridge, we feel warranted in saying it excels that of a great majority of bridges. — Editors.]

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of the bridge, to make it water-tight, and to prevent horses from slipping in travelling.

"We would say here, that about 40 feet of the bridge, and in different sections of the same, are laid blocks of chestnut wood, from New Hampshire.

"Under the sidewalks, the outside stringer is 12 inches wide, and the inside 6 by 12. On these are placed floor joists, 3 by 5 inches, covered by two inch plank. The railing is handsome and permanent; and near the draw is a wooden covering, with a 25 feet roof, for the convenience of pedestrians in inclement weather. The number of lamps and lamp posts are 22. The form of the bridge is a regular ascending plain, rising from the respective abutments to the draw, about 4 inches to every 100 feet."

The structure remained in the form in which it was thus repaired until 1846, when it was found that the blocks with which the surface was covered had decayed so much that it was necessary to remove them, and it was at length decided to cover the southern pine timbers, before referred to, with common two inch pine planks, and these again in the same manner. This is the form in which the surface is now covered, and it is, without doubt, the best method which has been made use of since the bridge was first built.

How long the blocks would have lasted under an ordinary amount of travel, we are not prepared to state; but it was found that the blocks at the outer edge of the bridge were in a tolerable state of preservation, while those in the centre were in a very decayed state.

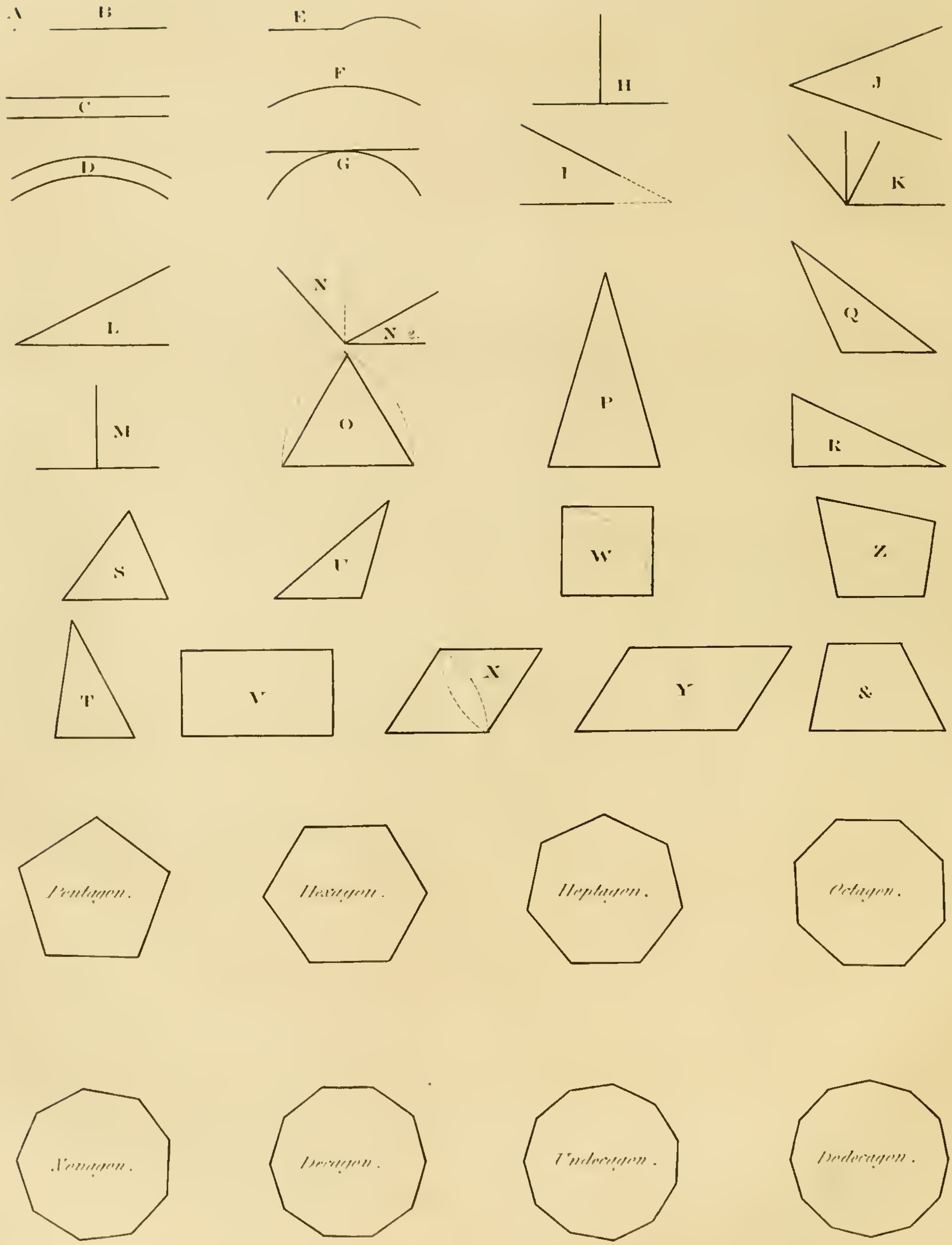
It may be well here to state, in order to give the reader some idea of the trave over this bridge, that from an account kept by order of Marshal Tukey, on Saturday, October 6, 1851, from half past six, A. M., until half past seven, P. M., as published in the Commonwealth newspaper at the time, was 3158 vehicles, 6223 passengers in the same, and 6995 passengers on foot. In consideration of this immense amount of travel, and also that the principal part of the vehicles consist of heavily-laded trucks and large freight wagons, it is a matter of astonishment that the blocks lasted as long as they did; for, as may be supposed, hollows and channels were soon formed in them, and the water standing in the same caused a constant decay.

In reference to this kind of paving, we would state, for the benefit of our readers, that it has been thoroughly tested in the streets of Boston, in some cases using hemlock, and in some others spruce but the same result as that with the pine on the bridge has followed and that now rough granite blocks, twelve inches square, are found to be the most serviceable as well as economical.

We ought perhaps to state in regard to the last repairs on Warren Bridge that, at the Boston end about the Fitchburg Depot, the timbers were lowered and covered with mud from the dock for about two feet deep, and upon this, in the centre of the bridge, as far as the draw, is placed granite blocks, as above described, and that the sidewalks for the same distance are paved with bricks. This method seems to work well, as yet, and it has been so highly approved that a new bridge which is now being erected on a new road leading from the Mill Dam Avenue to Brookline is constructed for the entire length in the same manner.

To our respected friend, Ebenezer Barker, Esq., who is superintending the new bridge, we tender our acknowledgments for his gentlemanly and kind assistance in procuring the facts relative to this important structure — the Warren Bridge. — Editors.

Pl. I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CIVIL ARCHITECTURE.

PRACTICAL GEOMETRY.

The System of Geometry here introduced is as concise and simple as is compatible with a proper understanding of this interesting branch of mechanical science.

Descriptive Geometry is employed to communicate a knowledge of different objects. It furnishes the means of constructing geographical charts, plans of buildings and machines, architectural designs, sun dials, &c. It is used, likewise, to describe the forms and relative positions of objects. By it, stone cutters, carpenters, shipbuilders, &c., find the dimensions of the works which they execute, inasmuch as these dimensions admit of a rigorous definition.

That a knowledge of Geometry is essential to the greater part of our practical mechanics, does not admit of a doubt; yet they have too generally regarded the subject with a degree of indifference, as though the ends proposed to be accomplished by it could be as accurately, and much more easily, attained by other means. This erroneous notion, however, is fast giving way to the force of truth and demonstration; and perhaps more attention is paid to the subject at the present time, by operative mechanics, than at any previous period since the discovery of the science. Many attempts have been made to simplify the study, and to render the acquisition of it more easy to the learner. In many instances, these attempts have been partially successful; but the student will bear in mind the memorable reply of Euclid — "*There is no royal road to geometry.*" There is no turnpike, though there are some cross roads; but we doubt not that he who travels the old road, which has been so often proved to be good, and over which so many have travelled before him, will be as well pleased with his journey when it is accomplished as he who arrives at the end by a shorter route. It has been said, but we trust with more severity than truth, that the generality of mechanics are displeased at the sight of a geometrical theorem. If so, a very little attention to the subject will satisfy them that no study can be better calculated to awaken the dormant faculties of the mind and to *force* them into action.

DEFINITIONS.

Plate 1.

1. Geometry is that science which treats of the descriptions and properties of magnitudes in general.

2. A *point* has neither parts nor magnitude, as A.

3. A *line* is length, without breadth or thickness, as B.

4. *Superficies* has length and breadth only.

5. A *solid* is a figure of three dimensions, having length, breadth, and thickness. Hence, surfaces are the extremities of solids, and lines the extremities of surfaces, and points the extremities of lines.

6. *Lines* are either right, curved, or mixed, as E.

7. A *right* or *straight line* lies in the same direction between its extremities, and is the shortest distance between two points.

8. A *curve* continually changes its directions between its extreme points, as F.

9. *Lines* are either parallel, oblique, perpendicular, or tangential.

10. *Parallel lines* are always at the same distance, and will never meet, though ever so far produced, as C and D.

11. *Oblique right lines* in the same plane change their distance, and would meet, if produced, as I.

12. One *line* is perpendicular to another when it inclines no more to one side than another, as H.

13. One *line* is tangent to another when it touches it without cutting, when both are produced, as G.

14. An *angle* is the inclination of two lines towards one another, meeting in a point, as J.

15. *Angles* are either right, acute, or oblique, as K.

16. A *right angle* is that which is made by one line perpendicular to another, or when the angles on each side are equal, as M.

17. An *acute angle* is less than a right angle, as N, 2.

18. An *obtuse angle* is greater than a right angle, as N.

19. *Superficies* are either plane or curved.

20. A *plane*, or *plane surface*, is that to which a right line will every way coincide; but if not, it is curved.

21. *Plane figures* are bounded either by right lines or curves.

22. *Plane figures*, bounded by right lines, have names according to the number of their sides or angles, for they have as many sides as angles. The least number is three.

23. An *equilateral triangle* is that whose three sides are equal, as O.

24. An *isosceles triangle* has only two sides equal, as P.

25. A *scalene triangle* has all its sides unequal, as Q or U.

26. A *right angled triangle* has one right angle, as R.

27. Other *triangles* are oblique angled, and are either obtuse or acute.

28. An *acute angled triangle* has all its angles acute, as S or T.

29. An *obtuse angled triangle* has one obtuse angle, as U.

30. A *figure* of four sides and angles is called a quadrangle, or quadrilateral, as V, W, X, Y, Z, &.

31. A *parallelogram* is a quadrilateral, which has both pairs of its opposite sides parallel, as V, W, X, Y, and takes the following particular names: —

32. A *rectangle* is a parallelogram, having all its angles right ones, as V and W.

33. A *square* is an equilateral rectangle, having all its sides equal, and all its angles right ones, as W.

34. A *rhombus* is an equilateral parallelogram, whose angles are oblique, as X.

35. A *rhomboid* is an oblique-angled parallelogram, as Y.

36. A *trapezium* is a quadrilateral, which has neither pair of its sides parallel, as Z.

37. A *trapezoid* has only one pair of its opposite sides parallel, as &.

38. *Plane figures* having more than four sides are, in general, called *polygons*, and receive other particular names, according to the number of their sides or angles.

39. A *pentagon* is a polygon of five sides. A *hexagon* has six sides, a *heptagon* seven, an *octagon* eight, a *nonagon* nine, a *decagon* ten, an *undecagon* eleven, and a *dodecagon* twelve sides.

40. A *regular polygon* has all its sides and angles equal; and if they are not equal, the polygon is irregular.

41. An *equilateral triangle* is also a regular figure of three sides, and a *square* is one of four — the former being called a *trigon*, and the latter a *tetragon*.

Plate 2.

42. A *circle* is a plane figure bounded by a curve line, called the *circumference*, which is every where equidistant from a certain point within, called its *centre*.

43. The *radius of a circle* is a right line drawn from the centre to the circumference, *a b*, at A.

44. A *diameter of a circle* is a right line drawn through the centre, terminating on both sides of the circumference, as *c d*, at B.

45. An *arc of a circle* is any part of the circumference.

46. A *chord* is a right line joining the extremities of an arc, as *a b*, at C.

47. A *segment* is any part of a circle bounded by an arc and its chord, as D.

48. A *semicircle* is half the circle, or a segment cut off by the diameter, as E.

49. A *sector* is any part of a circle bounded by an arc and two radii, drawn to its extremities, as F.

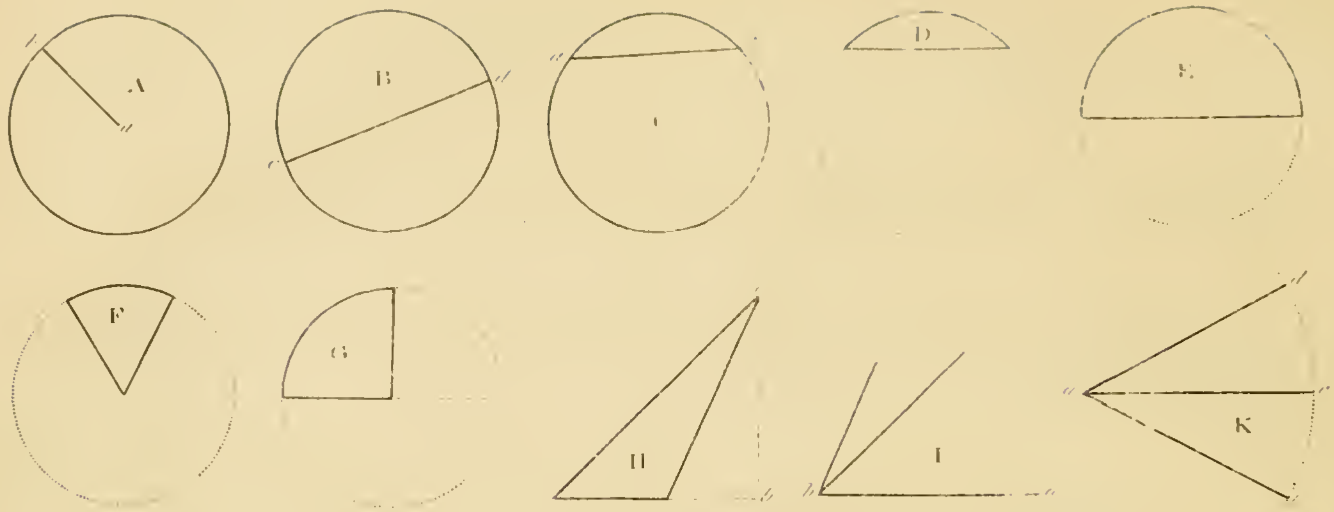
50. A *quadrant*, or quarter of a circle, is a sector, having a quarter of the circumference for its arc, and the two radii are perpendicular to each other, as G.

51. The height or altitude of any figure is a perpendicular let fall from an angle, or its vertex, to the opposite side, called the *base*, as *a b*, at H.

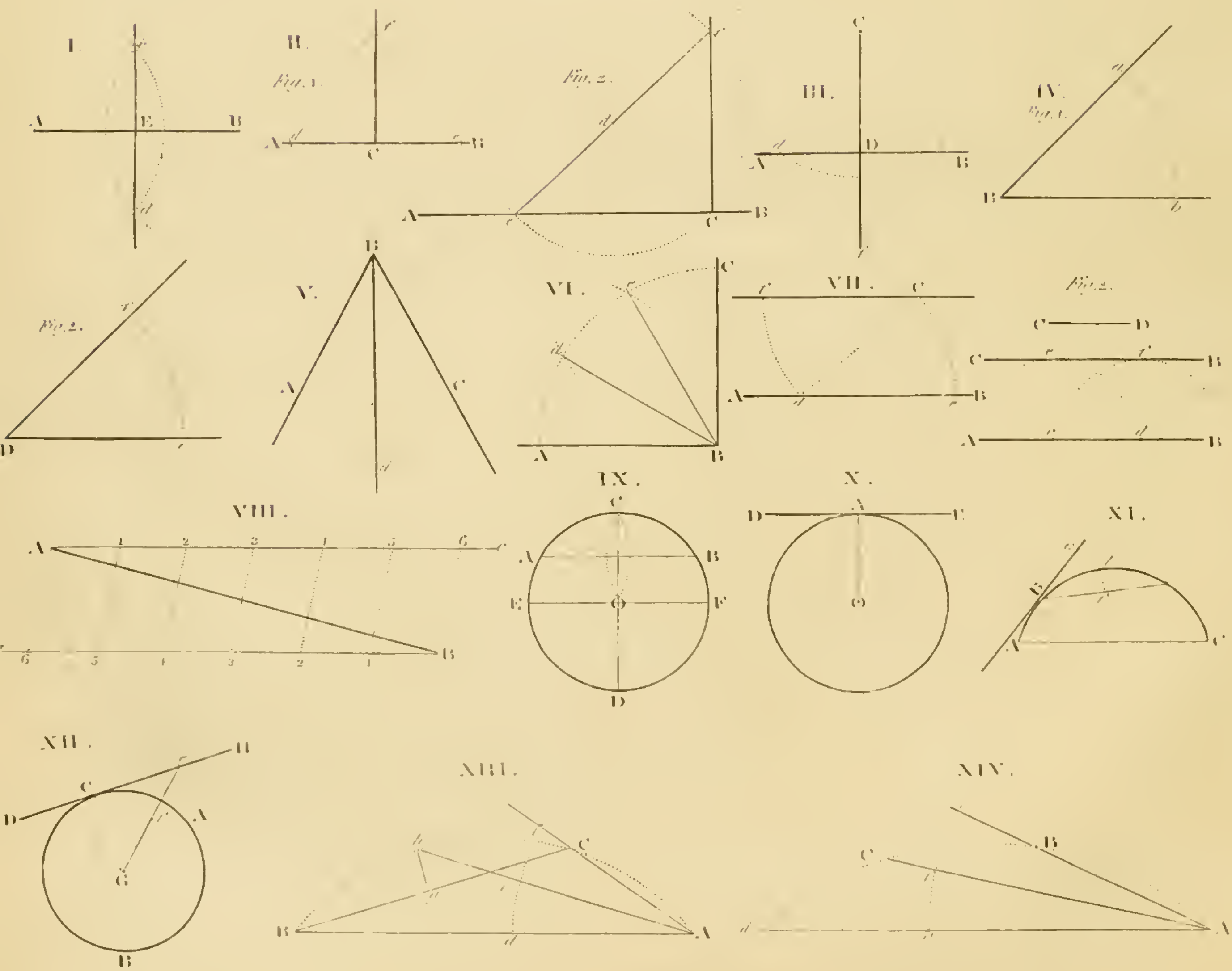
52. When an angle is denoted by three letters, the middle one is the place of the angle, and the other two denote the sides containing that angle. Thus: let *a b c* be the angle at I, then *b* will be the angular point, and *a b* and *b c* will be the two sides containing that angle.

53. The measure of any right-lined angle is an arc of any circle contained between the two lines which form the angle, the angular point being in the centre, as K. Thus, if the arc *b c d* be double of the arc *b c*, then the angle *b a d* will be double that of *b a c*.

Pl. 2



PROBLEMS.



PROBLEMS.

Plate 2.

PROBLEM I.

To bisect a given line, A B.

1. From the points A and B, as centres, with any distance greater than half A B, describe arcs cutting each other in *c* and *d*.

2. Draw the line *c d*, and the point E, where it cuts A B, will be the middle of the line required.

PROBLEM II.

From a given point, C, in a given right line, A B, to erect a perpendicular.

Fig. 1. *When the point is near the middle of the line.*

1. On each side of the point C take any two equal distances, C *d* and C *e*.

2. From *d* and *e*, with any radius greater than C *d*, or C *e*, describe two arcs cutting each other in *f*.

3. Through the points *f* C, draw the line *f* C, and it will be the perpendicular required.

Fig. 2. *When the point is at, or near, the end of the line.*

1. Take any point *d* above the line, and with the radius or distance, *d* C, describe the arc *e* C *f*, cutting A B in *e* and C.

2. Through the centre *d* in the point *e*, draw the line *e d f*, cutting the arc *e* C *f*, in *f*.

3. Through the points *f* C draw the line *f* C, and it will be the perpendicular required.

PROBLEM III.

From a given point, C, out of a given right line, A B, to let fall a perpendicular.

1. From the point C, with any radius, describe the arc *d e*, cutting A B in *e* and *d*.

2. From the points *e d* with the same, or any other radius, describe two arcs cutting each other in *f*.

3. Through the points C *f* draw the line C D *f*, and C D will be the perpendicular required.

PROBLEM IV.

At a given point, D, upon the right line, D E, to make an angle equal to a given angle, *a* B *b*.

1. From the point B, with any radius, describe the arc *a b*, cutting the legs B *a*, B *b*, in the points *a* and *b*.

2. Draw the line D *e*, and from the point D, with the same radius as before, describe the arc *e f*, cutting D E in *e*.

3. Take the distance *b a*, and apply it to the arc *e f*, from *e* to *f*.

4. Through the points D *f* draw the line D *f*, and the angle *e* D *f* will be equal to the angle *b* B *a*, as was required.

PROBLEM V.

To divide a given angle, A B C, into two equal angles.

1. From the point B, with any radius, describe the arc A C.

2. From A and C, with the same or any other radius, describe arcs cutting each other in *d*.

3. Draw the line B *d*, and it will bisect the angle A B C, as was required.

PROBLEM VI.

To trisect or divide a right angle, A B C, into three equal angles.

1. From the point B, with any radius B A, describe the arc A C, cutting the legs B A and B C, in A and C.

2. From the point A and C, with the radius A B, or B C, cross the arc A C, in *d* and *e*.

3. Through the points *e d* draw the lines B *e*, B *d*, and they will trisect the angle, as was required.

PROBLEM VII.

Through a given point, C, to draw a line parallel to a given line, A B.

1. Take any point *d*, in A B, upon *d* and C, with the distance C *d*, describe two arcs, *e* C and *d f*, cutting the line A B, in *e* and *d*.

2. Make *d f* equal to *e* C; through C and *f* draw C *f*, which will be the line required.

Fig. 2. *When the parallel is to be at a given distance,* C D *from* A B.

1. From any two points *c* and *d*, in the line A B, with a radius equal to C D, describe the arcs *e* and *f*.

2. Draw the line C B, to touch those arcs without cutting them, and it will be parallel to A B, as was required.

PROBLEM VIII.

To divide a given line, A B, into any proposed number of equal parts.

1. From A, one end of the line, draw A *c*, making any angle with A B; and from B, the other end, draw B *d*, making the angle A B *d* equal to B A *c*.
2. In each of the lines A *c*, and B *d*, beginning at A and B, set off as many equal parts, of any length, as A B is to be divided into.
3. Join the points A 5, 1 4, 2 3, &c., and A B will be divided as was required.

PROBLEM IX.

To find the centre of a given circle, or one already described.

1. Draw any chord A B, and bisect it with the perpendicular C D.
2. Bisect C D with the diameter E *f*, and the intersection O will be the centre required.

PROBLEM X.

To draw a tangent to a given circle, that shall pass through a given point, A.

1. From the centre O, draw the radius O A.
2. Through the point A draw D E perpendicular to O A, and it will be the tangent required.

PROBLEM XI.

To draw a tangent to a circle, or any segment of a circle, A B C, through a given point, B, without making use of the centre of the circle.

1. Take any two equal divisions upon the circle; from the given point B, towards *d* and *e*, draw the chord *e* B.
2. Upon B, as a centre, with the distance B *d*, describe the arc *f d g*, cutting the chord *e* B, in *f*.
3. Make *d g* equal to *d f*, through *g* draw *g* B, and it will be the tangent required.

PROBLEM XII.

A circle, A B C, being given, and a tangent, D H, to that circle, to find the point of contact.

1. Take any point *e*, in the tangent D H; from *e*, to the centre of the circle G, draw *e* G.
2. Bisect *e* G, in *f*, and with the radius *f e*, or *f* G, describe the semicircle *e* C G, cutting the tangent and the circle in C; it will be the point required.

PROBLEM XIII.

Given three points, A B C, not in a straight line, to find a number of points lying between them, so that they shall all be in the circumference of a circle, without drawing any part of the circle, or finding the centre.

1. From A, through B and C, draw A B and A *f*.
2. On A, as a centre, with any radius A *f*, describe an arc *f e d*, cutting A B in *d*, and A C in *f*.
3. Bisect arc *d f* in *e;* through *e* draw A *e h*.
4. Join C B, bisect it in *g*, draw *g h* perpendicular, cutting A *e h* at *h*, then *h* will also be in the same circumference with A C B. In the same manner may a point be found between C *h* and *h* B.

PROBLEM XIV.

Given three points, A B C, not in a right line, to find another point without these points, so that the four points shall all be in the circumference of a circle, without drawing any part of the circle, or finding the centre.

1. Draw A *e* and A C, from A, through B and C.
2. On A, as a centre, with any radius A *e*, draw the arc *e f g*, cutting A B in *e*, and A C in *f*.
3. Make *f g* equal to *f e*, through A and *g* draw A *g* indefinitely towards *d*.
4. Upon C, with the distance C B, cross the line A *g* at *d;* it will be the point required.

If a fifth point, or any other number of points, are required, the process will be the same.

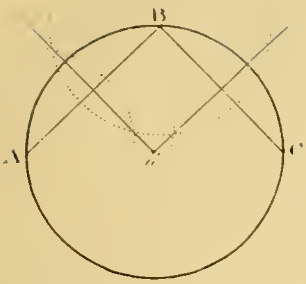
Plate 3.

PROBLEM XV.

Given three points, A B C, not in a straight line, to draw a circle through them.

1. Bisect the lines A B and B C by the perpendiculars, meeting at *d*.
2. Upon *d*, with the distance *d* A, *d* B, or *d* C, describe A B C; it will be the circle required.

XV.



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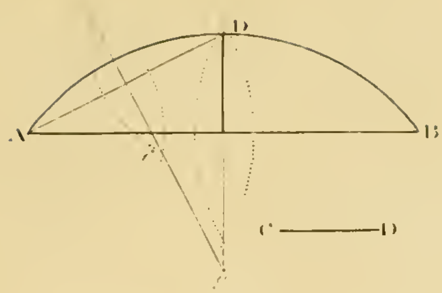

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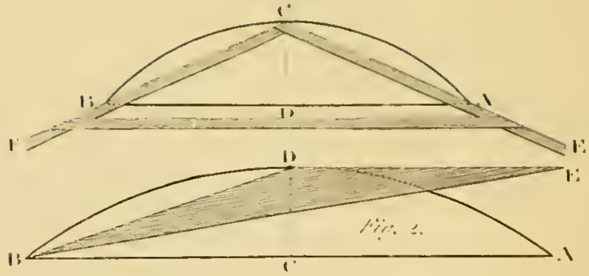

Fig. 4.

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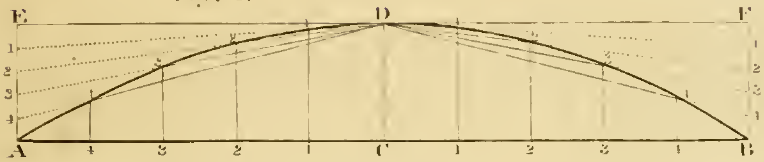

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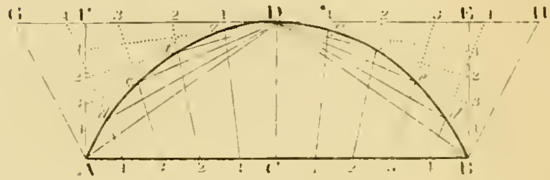

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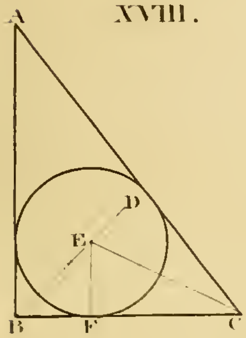

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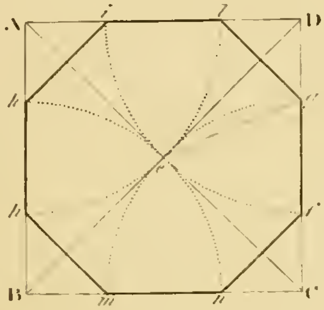

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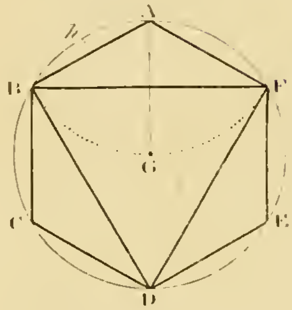

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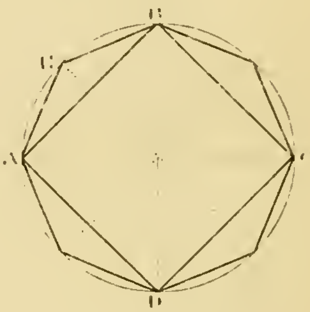

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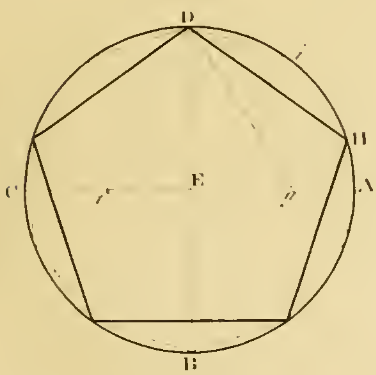

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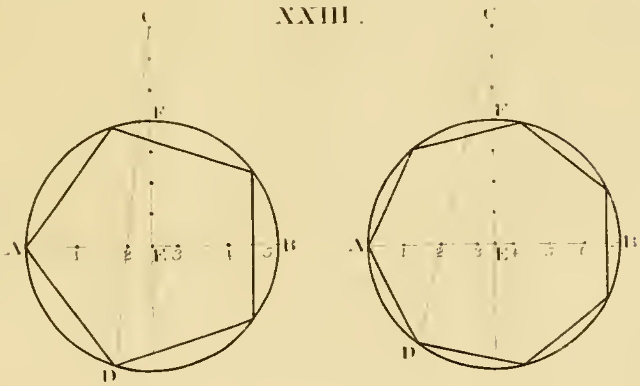

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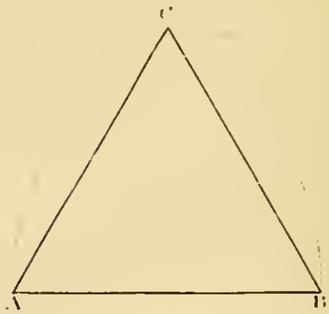

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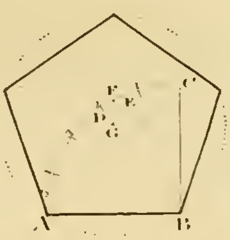
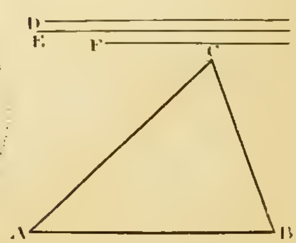


Fig. 2.

Fig. 3.

XXVII.



PROBLEM XVI.

To describe the segment of a circle to any length, A B, and breadth, C D.

1. Bisect A B, by the perpendicular D *g*, cutting A B in C.

2. From *c*, make *c* D on the perpendicular equal to C D.

3. Bisect A D, by a perpendicular *e f*, cutting D *g* in *g*.

4. Upon *g*, the centre, describe A D B; it will be the segment required.

PROBLEM XVII.

To describe the segment of a circle, by means of two rules, to any length, A B, and perpendicular height, C D, in the middle of A B, without making use of the centre.

It will be most convenient for practice to make the rules C E and C F each equal to A B, as room is sometimes wanted.

1. Place the rules to the height at C, bring the edges close to A and B, tack them together at C, and fix a rod across to keep them tight.

2. Put in pins at A and B, then move your rules round these pins; hold a pencil to the angular point at C; it will describe the segment required.

Fig. 2. *By means of a triangle.*

Let A B be the length of the segment, and C D the perpendicular height in the middle.

1. Through the points D and B draw D B.

2. Draw D E parallel to A B for conveniency; make D E equal to D B, and join E B.

3. Make a triangle E D B; put in pins at the points A D B; then move your triangle round the points D and B, and the angular point will describe half the segment; the other half will be described in the same manner, which will complete the whole segment, as was required.

Fig. 3. *Another method, by means of points.*

Let A B be the length, and C D, bisecting A B, the perpendicular height.

1. Through D, draw G H parallel to A B.

2. Draw D B, the half chord.

3. From B, make B H perpendicular to D B, cutting G H in H, and make D G equal to D H.

4. Draw A F and B E, each perpendicular to A B, cutting G H in F and E.

5. Divide D G, D H, C A, C B, and A F, B E, each into a like number of equal parts, as five.

6. Draw the cross lines, 4 4, 3 3, 2 2, 1 1, &c.

7. From the division on A F, and B E, draw lines to D, cutting the other cross lines at *d*, *e*, *f*, *g*, &c.

8. Put pins in these points, bend a slip round them, and draw the curve by it, which will be the segment required.

Fig. 4. *Another method, by points nearly true, when the segment is very flat.*

Let A B be the length, and C D, bisecting A B, the perpendicular height.

1. Draw A E and B F, perpendicular to A B, each equal to C D.

2. Divide C B and C A each into the same number of equal parts, as five.

3. From the points 4, 3, 2, 1, &c., on A B, draw the perpendicular 4 4, 3 3, 2 2, 1 1, &c., to A B.

4. Divide A E and B F into five equal parts each.

5. Draw lines from the points 1, 2, 3, 4, 5, at each end, to D, and complete the segment in the same manner as fig. 3.

PROBLEM XVIII.

To describe a circle within a given triangle, so that A B C will be tangical.

1. Take equal distances on C A, also on C B, from C; intersect towards D.

2. Draw lines E D, from A and C, through the intersection E and D; from E let fall a perpendicular, which will be the radius of the circle required.

PROBLEM XIX.

In a given square, A B C D, to inscribe a regular octagon.

1. Draw the diagonals A C and B D, intersecting at *e*.

2. Upon the points A B C D, as centres, with a radius *e* C, describe arcs *h e l*, *k e n*, *m e g*, *f e i*.

3. Join *f n*, *m h*, *k i*, *l g*; it will be the octagon required.

PROBLEM XX.

In a given circle to inscribe an equilateral triangle, a hexagon, or a dodecagon.

For the Equilateral Triangle.

1. Upon any point A, in the circumference, with the radius A G, describe the arc B G F.
2. Draw B F, make B D equal to B F.
3. Join D F, and B D F will be the equilateral triangle required.

For the Hexagon.

Carry the radius A G six times round the circumference; the figure A B C D E F will be the hexagon.

For the Dodecagon.

Bisect the arc A B in *h*, and A *h* being carried twelve times round the circumference, will also form the dodecagon.

PROBLEM XXI.

In a given circle to inscribe a square or an octagon.

1. Draw the diameters A C and B D at right angles.
2. Join A B, B C, C D, D A, and A B C D will be the square.

For the Octagon.

Bisect the arc A B in E, and A E being carried eight times round, will also form the octagon.

PROBLEM XXII.

In a given circle to inscribe a pentagon or a decagon.

For a Pentagon.

1. Draw the diameters A C and B D at right angles.
2. Bisect B C in *f*, upon *f;* with the distance *f* D describe the arc D *g* upon D; with the distance D *g* describe the arc *g* H, cutting the circle in H.
3. Join D H, and carry it round the circle five times, which will form the pentagon.

For the Decagon.

Bisect the arc D H in *i*, and D *i* being carried ten times round, will also form the decagon.

PROBLEM XXIII.

In a given circle to inscribe any regular polygon.

1. Draw the diameter A B, from E the centre; erect the perpendicular E F C, cutting the circle at F.
2. Divide E F into four equal parts, and set three parts from F to C.
3. Divide the diameter A B into as many equal parts as the polygon is required to have sides.
4. From C, through the second division in the diameter, draw C D.
5. Join A D; it will be the side of the polygon required.

PROBLEM XXIV.

Upon a given line, A B, to describe an equilateral triangle.

1. Upon the points A and B, with a radius equal to A B, describe arcs cutting each other at C.
2. Draw A C and B C; it will be the triangle required.

PROBLEM XXV.

Upon a given line, A B, to describe a square.

1. Upon A and B, as centres, with a radius A B, describe two arcs, A *e* C, B *e* D, cutting each other at *e*.
2. Bisect A *e* at *f;* from *e* make *e* D and *e* C equal to *e f*.
3. Join A D, D C, C B, and it will be the square required.

PROBLEM XXVI.

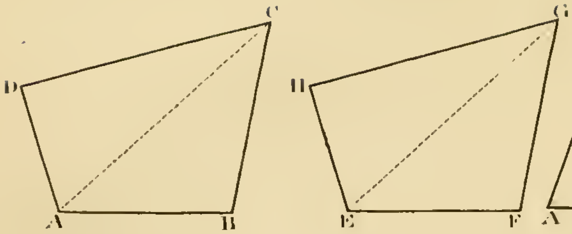
Upon a given line, A B, to construct any regular polygon.

1. Upon A and B, as centres, with a radius A B, describe two arcs intersecting each other at F.
2. From B, draw B C perpendicular, and divide the arc A C into as many equal parts as the polygon is to have sides.
3. Through the second division D draw B G, make F E equal to F D, and through E draw A G, meeting B G at G; then G will be the centre, and G A the radius of a circle, that will contain A B to any number of sides required.

PROBLEM XXVII.

To make a triangle, whose three sides shall be

XXVIII.



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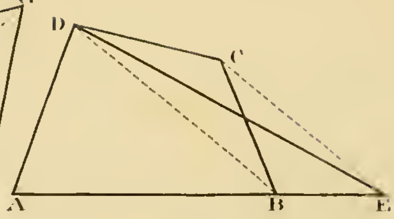

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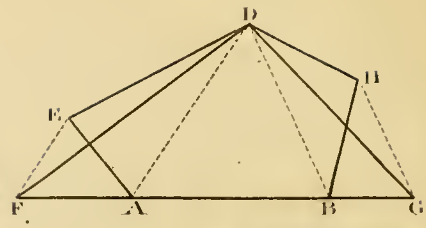

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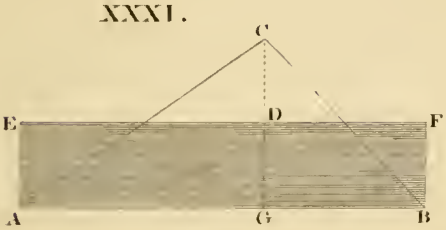

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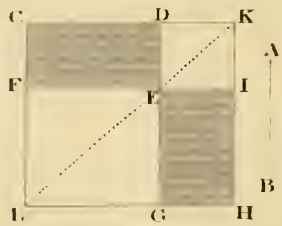

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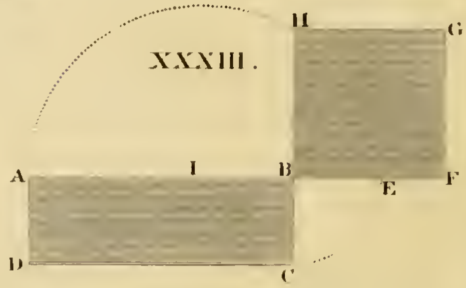

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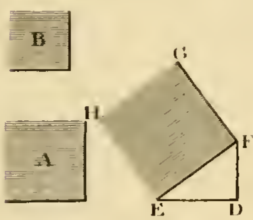

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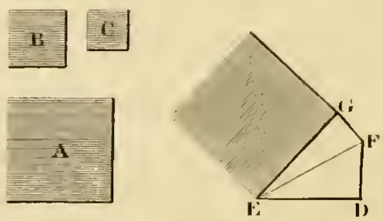

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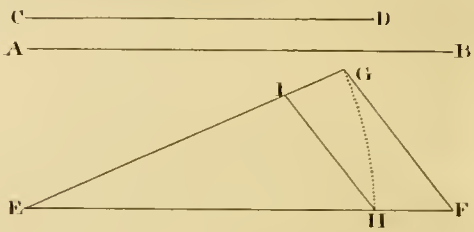

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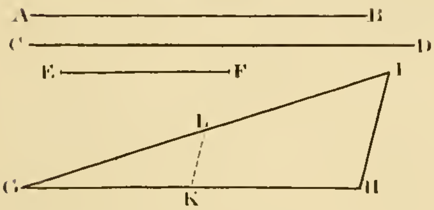

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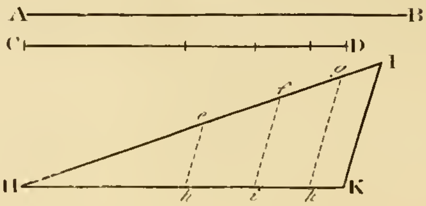

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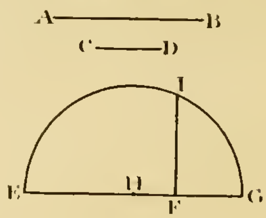

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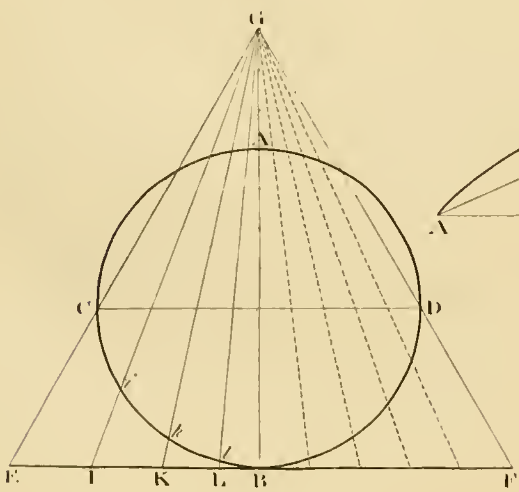
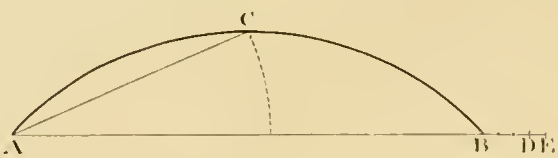
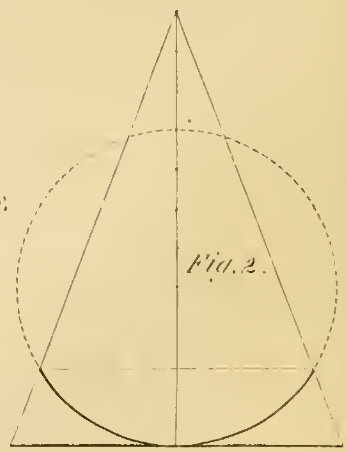


XLI.



XL.



equal to three given lines, D, E, F, if any two are greater than the third.

1. Draw A B equal to the line D.

2. Upon B, with the length of E, describe an arc at C.

3. Upon B, with the length F, describe another arc, intersecting the former at C.

4. Draw A C and C B, and A B C will be the triangle required.

Plate 4.

PROBLEM XXVIII.

To make a trapezium equal and similar to a given trapezium, A B C D.

1. Divide the given trapezium A B C D into two triangles, by a diagonal, A C.

2. Make E F equal to A B upon E F, construct the triangle E F, whose three sides will be respectively equal to the triangle A B C.

3. Upon E G, which is equal to A C, construct the triangle E G H, whose two sides, E H and G H, are respectively equal to A D and C D, then E F G H will be the trapezium required.

In the same manner may any irregular polygon be made equal and similar to a given irregular polygon, by dividing the given polygon into triangles, and constructing the triangles in the same manner in the required polygon, as is shown by figures.

PROBLEM XXIX.

To make a triangle equal to a given trapezium, A B C D.

1. Draw the diagonal B D, make C E parallel to to it, meeting the side A B, produced in E.

2. Join D E, and A D E will be the triangle.

PROBLEM XXX.

To make a triangle equal to a given right-lined figure, A B C D E.

1. Produce the side A B both ways at pleasure.

2. Draw the diagonals A D and B D, and make E F and G H parallel to them.

3. Join D F, D G, then D F G will be the triangle required.

Much after the same manner may any other right-lined figure be reduced to a triangle.

PROBLEM XXXI.

To reduce a triangle, A B C, to a rectangle.

1. Bisect the altitude C G, in D; through D draw E F parallel to A B.

2. From B draw B F perpendicular to A B, through A draw A E parallel to B F, then A B F E will be the rectangle required.

PROBLEM XXXII.

To make a rectangle, having a side equal to a given line, A B, and equal to a given rectangle, C D E F.

1. Produce the sides of the rectangle C F, D E, F E, and C D.

2. Make E G equal to A B, through G draw L H parallel to F E, cutting C F produced at L.

3. Draw the diagonal L E, and produce it till it cut C D at K.

4. Draw K H parallel to E G, then will E I H G be the rectangle required.

PROBLEM XXXIII.

To make a square equal to a given rectangle, A B C D.

1. Produce the side A B, make B E equal to B C.

2. Bisect A E, in I; on I, as the centre, with the radius I E or I A, describe the semicircle A H E.

3. Produce the side of C B to cut the circle in H; on B H describe the square B H G F; it will be the square required.

PROBLEM XXXIV.

To make a square equal to two given squares, A and B.

1. Make D E equal to the side of the square A, and D F perpendicular to D E, equal to the side of the square B.

2. Draw the hypothenuse F E; on it describe the square E F G H; it will be the square required.

PROBLEM XXXV.

To make a square equal to three given squares, A B C.

1. Make D E equal to the side of the square A, and D F perpendicular to D E, equal to the side of the square B.

2. Join F E; draw F G perpendicular to it.

3. Make F G equal to the side of the square C; join G E, then G E will be the side of the square required.

PROBLEM XXXVI.

Two right lines, A B, and C D, being given, to find a third proportional.

1. Make an angle H E I at pleasure, from E, make E F equal to A B, and E G equal to C B; join F G.
2. Make E H equal to E G, and draw H I parallel to E G, then E I will be the third proportional required, that is, E F : E G : : E H : E I, or A B : C D : : C D : E I.

PROBLEM XXXVII.

Three right lines, A B, C D, E F, being given, to find a fourth proportional.

1. Make the angle, H G I, at pleasure; from G make G H equal to A B; G I equal to C D; and join H I.
2. Make G K equal to E F, draw K L through K parallel to H I, then G L will be the fourth proportional required; that is, G H : G I : : G K : G L, or A B : C D : : E F : G L.

PROBLEM XXXVIII.

To divide a given line, A B, in the same proportion as another, C D, is divided.

1. Make any angle K H I, and make H I equal to A B; then apply the several divisions of C D from H to K, and join K I.
2. Draw the lines *h e*, *i f*, *k g*, parallel to I K, and the line H I will be divided in *h*, *i*, *k*, as was required.

PROBLEM XXXIX.

Between two given right lines, A B, and C D, to find a mean proportional.

1. Draw the right line E G, in which make E F equal to A B, and F G equal to C D.
2. Bisect E G in H, and with H E or H G describe the semicircle E I G.
3. From F draw F I perpendicular to E G, cutting the circle in I, and I F will be the mean proportional required.

PROBLEM XL.

To find a line nearly equal to the circumference of its circle, A B C D.

1. Draw the diameters A B and C D at right angles.
2. Produce A B, till the part A G without be three quarters of the radius.
3. Draw E F through B, parallel to C D, through G, and the points C and D; draw G E and G F, cutting the tangent in E and F; then E and F will be equal to half the circumference.

Much after the same manner may a straight line be found equal to any part of a circle, as is shown at Fig. 2, but the following method is much better for small arcs, as it requires less room: —

Remark. — If any number of divisions E I, I K, K L, L B, are taken on E F, and from the points I, K, L, lines are drawn to G, to cut the circumference *i*, *k*, *l*, the divisions on the circle, viz., C *i*, *i k*, *k l*, *l* B, will be respectively equal to their corresponding divisions, E I, I K, K L, L B, on the tangent line E F; that is, to *k i*, and I E equal to *i* C.

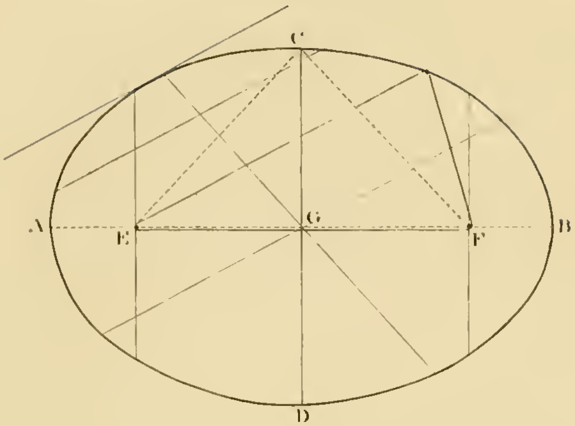
PROBLEM XLI.

To find the length of any arc, A C B, of a circle.

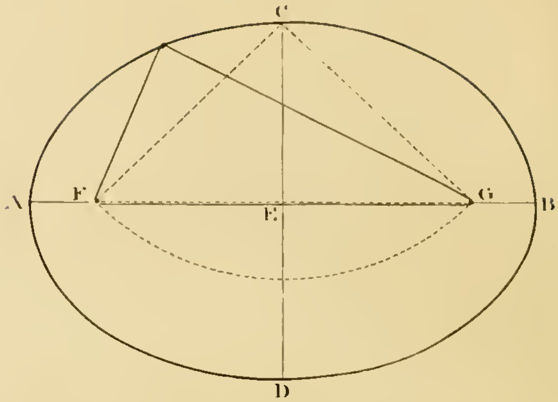
1. Draw the chord A B indefinitely towards E, and bisect the arc A C B at C.
2. Make A D equal to twice the half chord A C; divide B D into three equal parts, and set one towards E; then will A E be the length of the arc line A C B.

Definitions.

Of the Ellipsis.



PROB. I.



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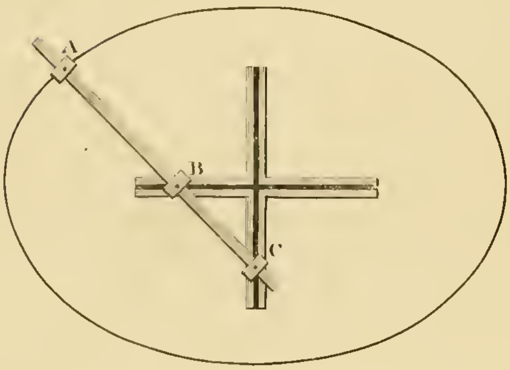

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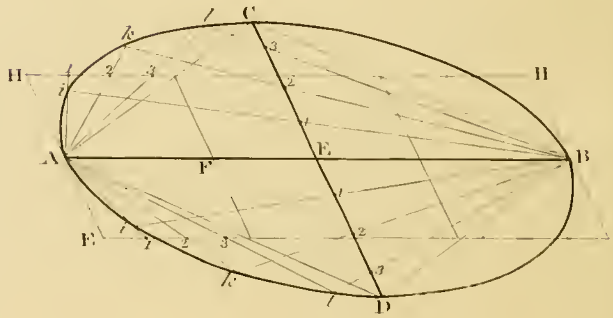

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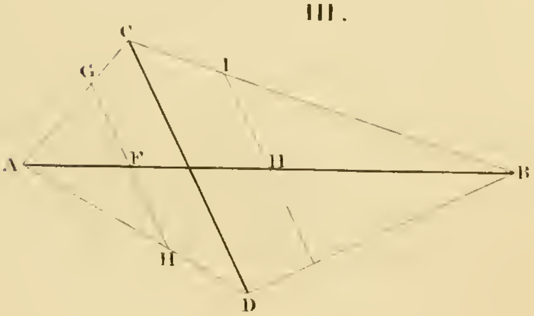

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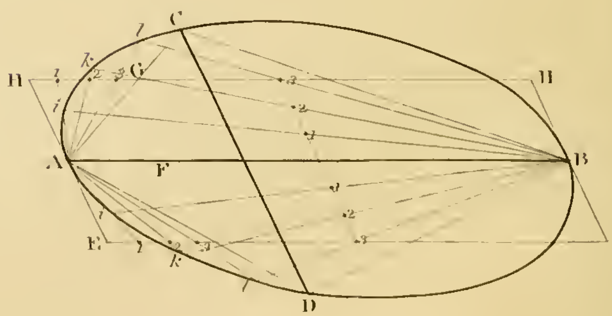


Fig. 2.

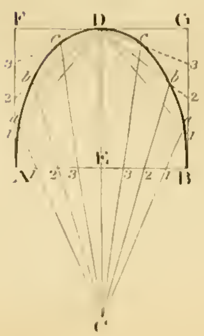
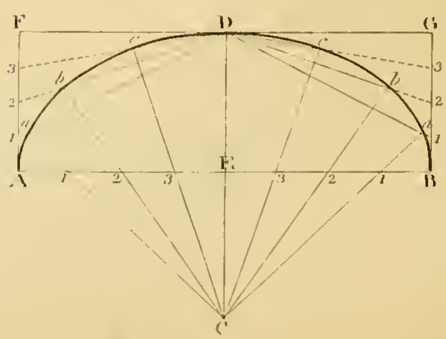


Fig. 3.



CONIC SECTIONS.

OF THE ELLIPSIS.

DEFINITIONS.

Plate 5.

1. If two pins are fixed at the points E and F, a string being put about them, and the ends tied together at C, the point C being moved round, keeping the string stretched, it will describe a curve called an *Ellipsis.*

2. *Foci* are the two points E and F, about which the string is made to revolve.

3. *Transverse axis* is the line A B, passing through the foci, and terminated by the curve at A and B.

4. *Centre* is the point G, bisecting the transverse axis A B.

5. *Conjugate axis* is the line C D bisecting the transverse axis at right angles, and terminated by the curve.

6. *Latus rectum* is a right line passing through the focus F, at right angles to the transverse axis, terminated by the curve. This is also called the *Parameter.*

7. *Diameter* is any line passing through the centre G, terminated by the curve.

8. *Conjugate diameter* is a right line drawn through the centre, parallel to a tangent at the extreme of the other diameter, and terminated by the curve.

9. *Double ordinate* is a line drawn through any diameter, parallel to a tangent at the extreme of that diameter, terminated by the curve.

PROBLEMS.

PROBLEM I.

The transverse and conjugate axes, A B, and C D, of an ellipsis being given, to find the two foci, from thence to describe an ellipsis.

1. Take the semitransverse A E, or E B, and from C, as a centre, describe an arc, cutting A B at F and G, which are the foci.

2. Fix pins in these points, a string being stretched about the points F C G; then move the point C round the fixed points F and G, keeping the string tight. It will describe the ellipsis as in the first definition.

PROBLEM II.

The same being given, as in the last problem, to describe an ellipsis, by an instrument called a trammel.

The trammel, as used by artificers, is two rules, with a groove in each, fixed together so that the grooves will be at right angles to each other. To this there is a rod with two movable nuts, and another fixed at the end, with a hole through it, to hold a pencil. On the under side of the sliding nuts are two round pins, made to fill the groove of the trammel, and are used as follows: —

Operation. — Set the distance of the first pin at B, from the pencil at A, to half the shortest axis, and the distance of the second pin at C, from A, to half the longest axis, the pins being put in the grooves, as is shown by the figure; then move the pencil at A. It will describe the ellipsis required.

PROBLEM III.

A diameter, A B, and a double ordinate, C D, to that diameter, being given, to find the parameter.

1. Join A C, A D, and B C, B D; bisect A B in H, through H draw H I parallel to D C, cutting B C in I.

2. From A, make A F equal to H I; through F draw G H parallel to C D, cutting A C in G, and A D in H; then G H is the parameter sought.

PROBLEM IV.

To describe an ellipsis by finding points in the curve, having the two conjugate diameters, A B and C D, given.

1. Find F G half the parameter; through G draw H H parallel to A B.

2. Draw E H parallel to C D, cutting H H at I.

3. Set off any number of equal divisions from H towards G. Set the same parts from E towards C.

4. From the point B, through the points 1, 2, 3, in E C, draw the lines B *i*, B *k*, B *l*.

5. From A, through the points in H G, draw the lines A *i*, A *k*, A *l*, intersecting the former lines in *i*, *k*, *l*. They will be in the periphery of the ellipsis.

PROBLEM V.

Having a diameter, and a double ordinate to that diameter, to describe the ellipsis, by finding points in the curve.

This problem will be completed in the same manner as Problem IV., and as is plainly shown by the figures 2 and 3.

Plate 6.

PROBLEM VI

To describe an ellipsis, or any segment of an ellipsis, having a diameter and a double ordinate, by means of points being found in the curve, without finding the parameter.

Let A B be the diameter or double ordinate, let C D be its conjugate, and let E D be the height of the segment.

1. Through D draw F G parallel to A B; also, through the points A and B draw A F and B G, parallel to D E, cutting F G in F and G.

2. Divide A E and E B into a like number of equal parts, as four; likewise B G and A F into the same number of equal parts.

3. From the point D, through the points 1, 2, 3, in A F and B G, draw 1 D, 2 D, 3 D.

4. From the point C, through the points 1, 2, 3, in A B, draw C *a*, C *b*, C *c*; cutting the lines 1 D, 2 D, 3 D, in *a*, *b*, *c*, they will be in the periphery of the ellipsis; a curve being traced through these points will form the ellipsis required.

But if the curve is very large, as in practical works, the best way is to put in nails or pins at the points *a*, *b*, *c*, &c., bend a slip round them, and draw a curve by it; it will appear quite regular.

PROBLEM VII.

To draw the representation of an ellipsis, with a compass, to any length, A B, and width, C D.

1. Draw B P parallel and equal to E C, and bisect it at 1, then draw 1 C and P D, cutting each other at K; bisect K C by a perpendicular, meeting C D at O; and on O, with the radius O C, describe the quadrant C G Q.

Through Q and A draw Q G, cutting the quadrant at G; then draw G O, cutting A B at M; make E L equal to E M; also E N equal to E O. From O, through M and L, draw O G and O K; likewise from N, through M and L, draw N H and N I; then M, L, N, O, are the four centres; by help of these, the four opposite sectors will be described.

Fig. 2. *To describe an ellipsis more accurately with a compass than the foregoing, having the two axes* A B *and* C D *given.*

1. Draw A 3 parallel and equal to E C, divide it into three equal parts, and draw 2 C and 1 C; then divide A E also into three equal parts, and from D, through the points 1, 2, in A E, draw D Q and D P, cutting the lines 1 C and 2 C, in Q and P.

2. Bisect C P by a perpendicular, meeting C D produced at S; join P S, cutting A E at X; then make E W equal to E X, and E U equal to E S; and through X and W draw P S and O S; also through the same points, X and W, draw U K and U L.

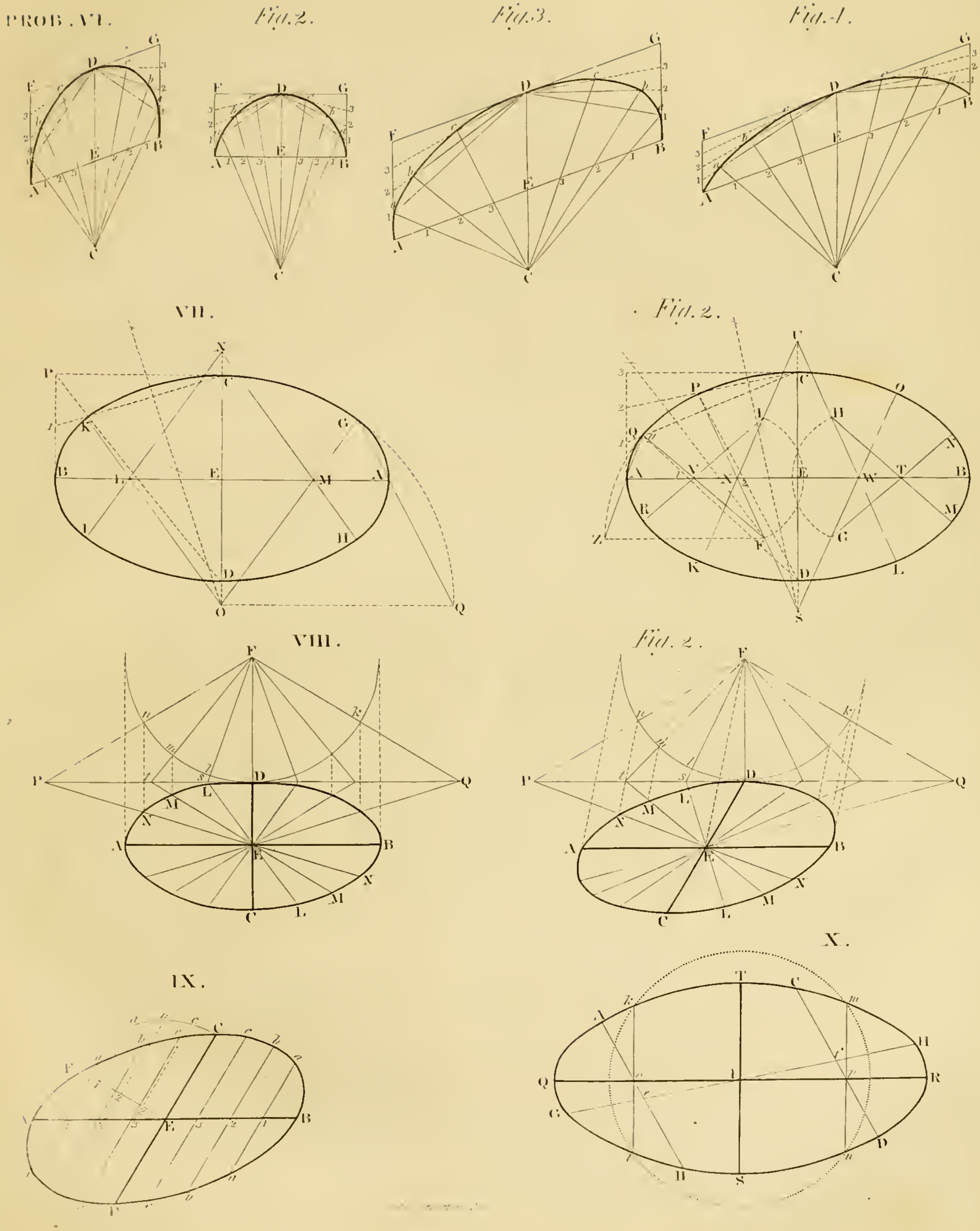
3. Bisect P Q by a perpendicular, meeting P S at F; draw Z F parallel to A B; then with the radius F Q describe the arc Q Z, cutting F Z at Z; through Z and A draw Z *y*, cutting the arc Z Q at *y*; and join *y* F, cutting A B at V. On X, make X I equal to X F; with the same radius on W make W H and W G; through V draw I R, make E T equal to E V, through T draw H M and G N; then U, S, G, H, I, F, T, V are the centres.

PROBLEM VIII.

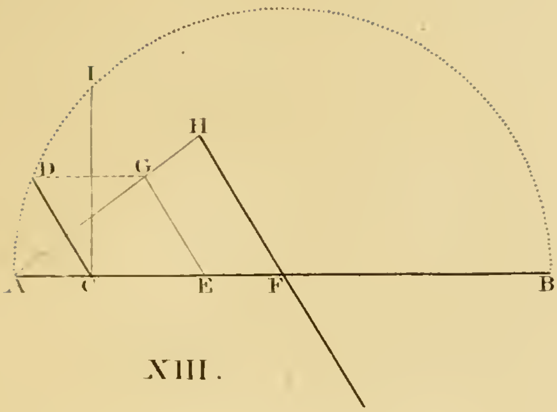
Having the two axes, or any other conjugate diameters, A B and C D, given, to describe an ellipsis through points, at the extremes of any diameters taken at pleasure.

1. Through D draw P Q, parallel to A B from D; draw D F perpendicular to P Q, and make it equal to E B, or E A; upon F, with the distance F D, describe the circle *n* D *k*.

2. Through the centre E draw the line P E N, *t* E M, *s* E L, &c., at pleasure, cutting the tangent P Q at P, *t*, *s*, &c. Join P F, *t* F, *s* F, &c., cutting the circle *n* D *k*, at the points *m* *n* *l*, &c.; likewise


PROB. VI.
Fig. 2.
Fig. 3.
Fig. 4.
VII.
Fig. 2.
VIII.
Fig. 2.
IX.
X.

PROB. XI.



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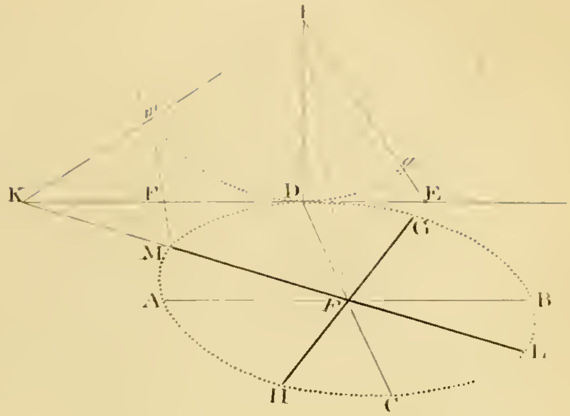

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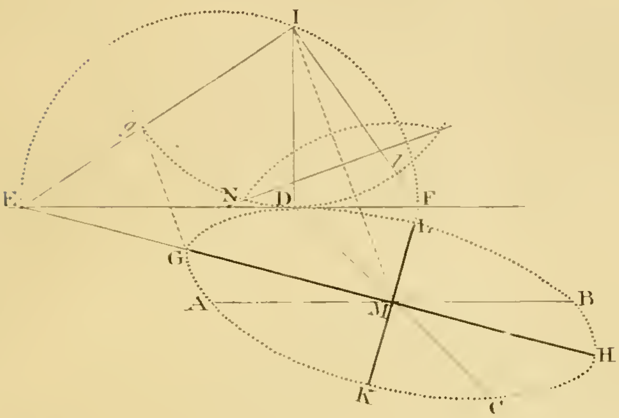
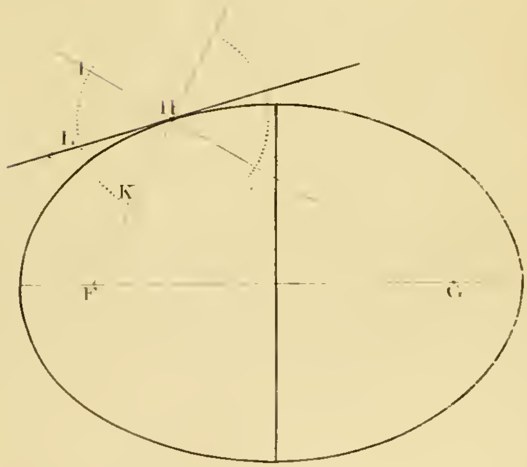


XIV.



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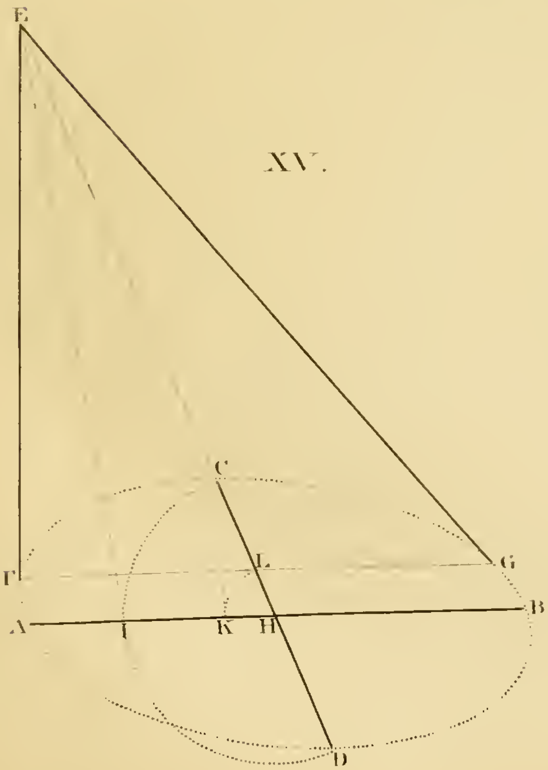
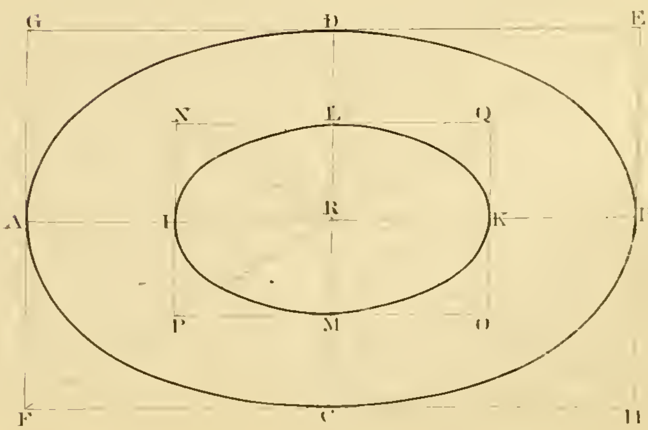


XVI.



join E F, if necessary, and draw *n* N, *m* M, *l* L, &c., parallel to it, cutting the diameters N N, M M, L L, &c., at N M L, &c.; then these points will be in the periphery of the ellipsis. If the diameters are produced to the opposite sides, at N M L, and the distances E N, E M, E L, &c., are made respectively to their corresponding opposite distances, E N, E M, and E L, &c., then the points N M L, on the under side of the diameter A B, will also be in the curve.

PROBLEM IX.

To draw an ellipsis by ordinates, having the axes, or any other conjugate diameters, A B, and C D, given.

1. From E, the centre, draw E F perpendicular to C D. Upon E, with the radius E C, describe the quadrant C F; divide E F into any number of equal parts, as four; from these points draw 1 *a*, 2 *b*, 3 *c*, parallel to E C, cutting the quadrant at *a*, *b*, and *c*.

2. Divide E A and E B each in the same number of equal parts; through the points 1, 2, 3, &c., draw *a a*, *b b*, *c c*, &c., parallel to C D.

3. Make the distances 1 *a*, 2 *b*, 3 *c*, &c., equal to their corresponding distances, 1 *a*, 2 *b*, on the quadrant; then the points *a*, *b*, *c*, &c., will be all in the periphery of the ellipsis.

PROBLEM X.

An ellipsis, A B C D, being given, to find the transverse and conjugate axes.

1. Draw any two parallel lines A B, and C D, cutting the ellipsis at the points A, B, C, D; bisect them in *e* and *f*.

2. Through *e* and *f* draw G H, cutting the ellipsis at G and H; bisect G H at I; it will give the centre.

3. Upon I, with any radius, describe a circle, cutting the ellipsis in the four points, *k*, *l*, *m*, *n*.

4. Join *k l*, and *m n;* bisect *k l*, or *m n*, at *o* or *p*.

5. Through the points *o* I, or I *p*, draw Q R, cutting the ellipsis at Q and R; then Q R will be the transverse axis.

6. Through I, draw T S parallel to *k l*, cutting the ellipsis at T and S, and T S will be the conjugate axis.

Plate 7.

PROBLEM XI.

Any diameter, A B, being given, and an ordinate, C D, to find its conjugate, without drawing any part of the ellipsis.

1. Draw C I perpendicular to A B; bisect A B in F, and draw F H parallel to C D.

2. On F, with the distance F A, or F B, describe the semicircle A I B, cutting C I at I.

3. Make A E equal to C I; draw E G parallel and equal to C D; through G and A draw A H, cutting F H at H; then F H is the semi-conjugate.

Much after the same manner, if two conjugate diameters are given, an ordinate may be found without drawing any part of the ellipsis.

PROBLEM XII.

Any two conjugate diameters, A B and C D, being given, and a right line, G H, passing through the centre, F, to find a diameter which will be conjugate to G H, without drawing any part of the ellipsis.

1. Through D draw E K parallel to A B, and produce the given line H G to cut the tangent in E.

2. From D, make D I perpendicular to E F, and equal to F A, or F B.

3. Join E I; from I, draw I K perpendicular to I E, cutting the tangent E K at K; through the centre F draw F K.

4. Through the points *g* and *m*, where the lines E I and I K cut the circle, draw *g* G and *m* M parallel to I F, cutting E F, and K F, at the points G and M; make F H equal to F G, and F L equal to F M; then M L and G H will be the two other conjugate diameters.

PROBLEM XIII.

Any two conjugate diameters, A B and C D, being given, to find the two axes, from thence to describe the ellipsis.

1. Through D draw E F, parallel to A B; draw D I perpendicular to E F, and equal to M A, or M B.

2. Upon I, with the radius I D, describe the arc *g* D *l*.

3. Join I M, and bisect it by a perpendicular, meeting the tangent E F at N.

4. On N, as a centre, with the distance N I, describe a semicircle E I F, cutting E F at the points E and F.

5. Through the centre M draw F K and E H.

6. Join I E and I F, cutting the arc *g* D *l* at *g* and *l*.

7. Draw *l* L and *g* G parallel to I M, cutting K F and H E at G and L. Make M K equal to M L, and M H equal to M G; then E H and K L will be the two axes required.

PROBLEM XIV.

An ellipsis being given, to draw a tangent through a given point H, in the curve.

1. Find the foci F and G; join F H and G H.

2. Produce C G H to I upon H, with any radius; describe the arc K L I, cutting G I and F H at K and I.

3. Bisect the arc K L I at L; through L and H draw L H; it will be the tangent required.

PROBLEM XV.

To draw two tangents to an ellipsis from a given point, E, without it having any two conjugate diameters, A B and C D, given, without drawing any part of the ellipsis.

1. Let the point E be in the diameter D C, produced.

2. From the centre H make H I equal to H C, and join I E.

3. Through C draw C K parallel to I E, cutting H A in K.

4. Make H L equal to H K; through L draw F G parallel to A B; find the extreme points F and G of the ordinate F G by Problem XI. From E, through the points F and G, draw E F and E G. They will be the tangents required.

If the point E is in neither of the given diameters A B or C D, when produced, draw a line from the given point E, through the centre; by Problem XII., find a conjugate to that line, and the extremities of both; then the construction will be the same as in this.

PROBLEM XVI.

To describe an ellipsis similar to a given one, A D B C, to any given length, I K, or to a given width, M L.

1. Let A B and C D be the two axes of the given ellipsis.

2. Through the points of contact, A, D, B, C, complete the rectangle G E H F; draw the diagonals E F and G H. They will pass through the centre at R.

3. Through I and K draw P N and O Q parallel to C D, cutting the diagonals E F and G H at P, N, Q, O.

4. Join P O and N Q, cutting C D at L and M; then I K is the transverse, M L the conjugate axis of an ellipsis that will be similar to the given one, A D B C, which may be described by some of the foregoing methods.

Plate 8.

PROBLEM XVII.

Given the rectangle A B C D, to circumscribe an ellipsis which shall have its two axes in the same ratio as the sides of the rectangle.

1. Draw the diagonals A C and B D, cutting each other at S, the centre.

2. Through S draw E F and G H parallel to A B and A D.

3. Upon S, with a radius, S I, equal to half A D or B C, describe the quadrant I K L cutting E F at L.

4. Bisect the arc I K L at K; through K draw M N parallel to E F, cutting the diagonal B D at N.

5. Join I N; through B draw B G parallel to it, cutting G H at G, and make S H equal to S G.

6. Join N O; through B draw B F parallel to it, cutting E F at F; make S E equal to S F; then E F and G H are the two axes which may be described by some of the methods which are shown in the foregoing problems.

PROBLEM XVIII.

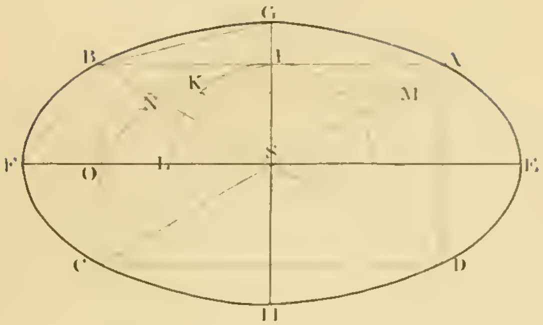
Given the trapezium, A B C D, and a point E, in one of the sides, to find a point in each of the other sides, so that, if an ellipsis was to be inscribed, it would touch the trapezium in these points.

1. Produce the sides of the trapezium till they meet at K and L.

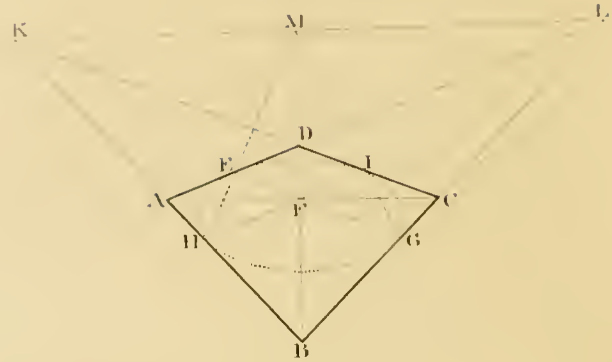
2. Draw the diagonals A C and B D, cutting each other at F; produce B D till it cut K L at M.

3. Through F, and the given point E, draw E G, cutting B C at G.

Pl 8 PROB. XVII.



XVIII.



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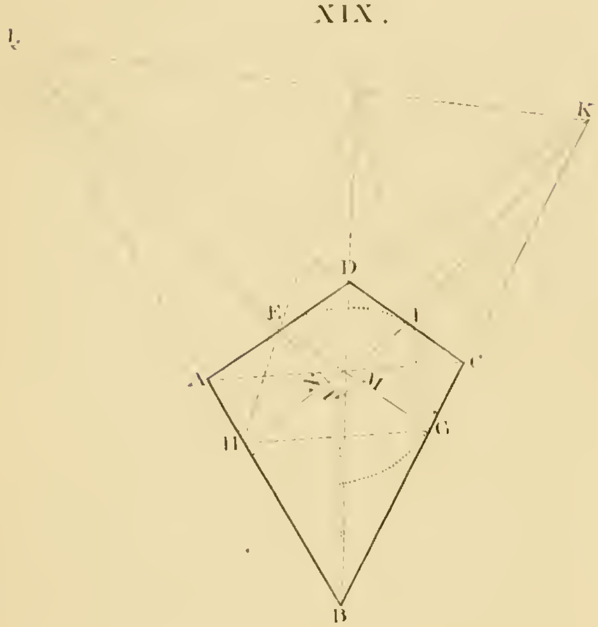

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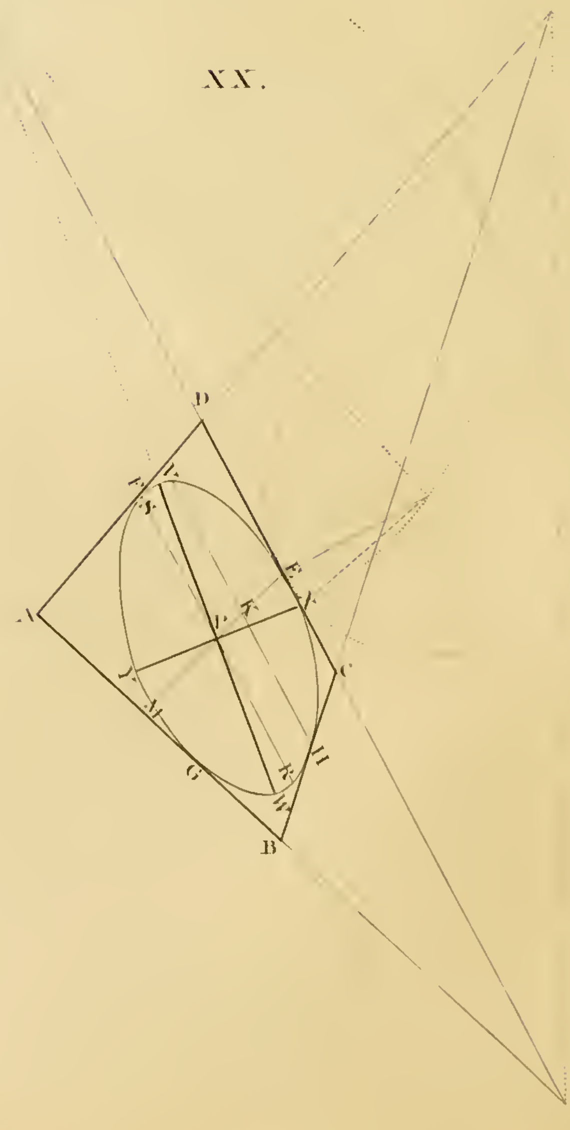
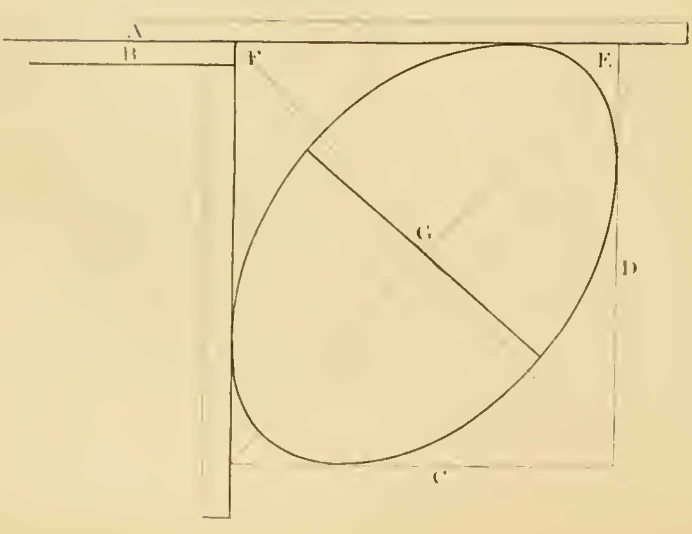
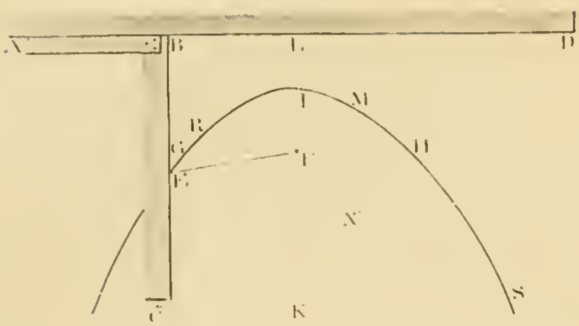


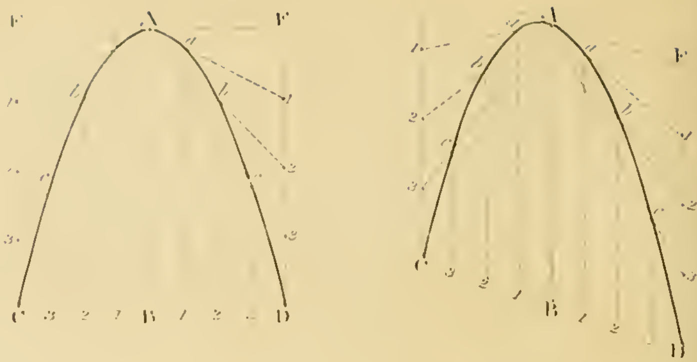
XXI.



Definitions. Of the Parabola.



PROB. I.



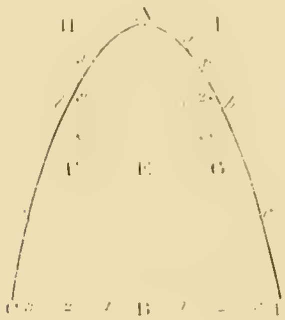
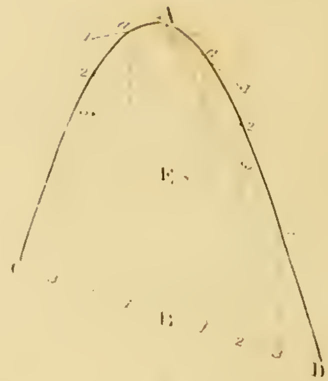
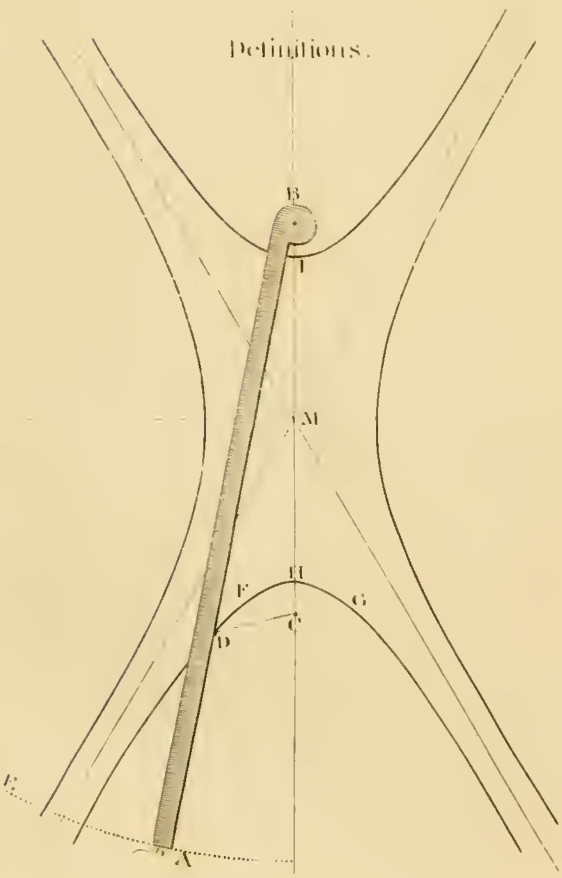
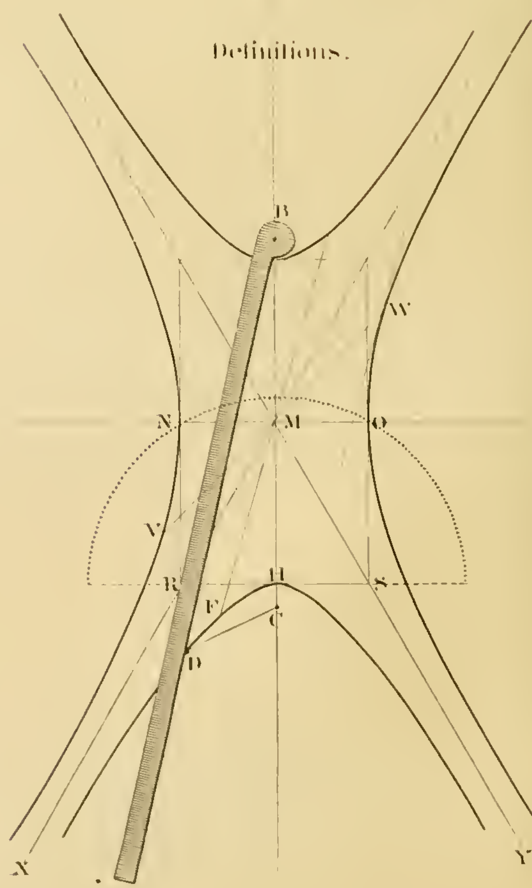


Fig. 2.



Definitions. Of the Hyperbola. Definitions.





4. From M, through the points E and G, draw M H and M G, cutting the other two sides in the points I and H, then E, H, G, I, will be the four points required.

PROBLEM XIX.

A trapezium, A B C D, being given, and a point E, in one of the sides, to find the centre of an ellipsis that may be described in the trapezium, and pass through the point of contact E, without drawing any part of the ellipsis.

1. Find the points of contact H, G, I, E, as in the last problem.

2. Join the points G and E by the right line G E, bisect it in M, and from K, where the opposite sides A D and B C meet, and through the point M, draw K M indefinitely.

3. Also join any other two points of contact, as H I; bisect H I at N, from L, where the opposite sides B A and C D meet; draw L N, meeting K M at P; then P will be the centre of the ellipsis required.

And, in like manner, if the points G and H were joined and bisected at Q, and a line being drawn from B where the opposite sides A B and C D meet through Q, it would also meet in P, the centre, &c.

PROBLEM XX.

Given a trapezium, A B C D, and a point E, in one of the sides, to find the two axes of an ellipsis that may be inscribed in the trapezium, and pass through the point E without drawing any part of the ellipsis.

1. Find the opposite points of contact, H, E, F, G, by Problem XVIII.

2. From thence, find the centre, P, by the last problem.

3. From E, and through the centre, P, draw E M, making P M equal to P E.

4. Through H, or any other point of contact, draw H K parallel to D C, cutting E M at K; then K H is an ordinate to the diameter E M.

5. Through P, the centre, draw P R parallel to H K.

6. Find the extremities R and S, of the diameter R S, by Problem XI.

7. The conjugate diameters E M and R S, being now found, then find the two axes, V W and X Y, by Problem XIII.

PROBLEM XXI.

To find the centre and transverse axis of an ellipsis by means of a square and rule.

1. Apply the square A B, Problem XXI.

2. Place the ellipsis tangical to A B, at pleasure.

3. Draw lines C D, touching the opposite sides of the ellipsis.

4. Draw lines E F, intersecting the ellipsis; and C is the centre, and E F the transverse axis required. Also, E F is equal, added together, in whatever direction the ellipsis may be applied to the square and rule.

OF THE PARABOLA.

DEFINITIONS.

Plate 9.

1. If a thread, equal in length to B C be fixed at C, the end of a square, A B C, and the other end fixed at F; and if the side A B, of the square, be moved along the right line, A D; and if the point E be always kept close to the edge B C, of the square, keeping the string tight, the point or pin E will describe a curve E G I H, called a *parabola*.

2. *Focus* is the fixed point F, about which the string revolves.

3. *Directrix* is the line A D, which the side of the square moves along.

4. *Axis* is the line L K, drawn through the focus F, perpendicular to the directrix.

5. *Vertex* is the point I, where the line L K cuts the curve.

6. *Latus rectum*, or *parameter*, is the line G H, passing through the focus F, at right angles to the axis I K, and terminated by the curve.

7. *Diameter* is any line M N, drawn parallel to the axis I K.

8. *Double ordinate* is a right line R S, drawn parallel to a tangent at M, the extreme of the diameter M N, terminated by the curve.

9. *Abscissa* is that part of a diameter contained between the curve and its ordinate, as M N.

PROBLEMS.

PROBLEM I.

To describe a parabola by finding points in the curve, the axis A B, or any diameter being given, and a double ordinate C D.

1. Through A draw E F parallel to C D.

2. Through C and D, draw D F and C E parallel to A B, cutting E F at E and F.

3. Divide B C and B D each into any number of equal parts, as four.

4. Likewise divide C E and D F into the same number of equal parts, viz., four.

5. Through the points 1, 2, 3, &c., in C D, draw the lines 1 *a*, 2 *b*, 3 *c*, &c., parallel to C D.

6. Also through the points 1, 2, 3, in C E and D F, draw the lines 1 A, 2 A, 3 A, cutting the parallel lines at the points *a*, *b*, *c*, then the points *a*, *b*, *c* are in the curve of the parabola.

Fig. 2. *Another method.*

1. Join A C and A D; from A make A E equal to B C or B D.

2. Through A and E, draw H I and F G parallel to C D, cutting A C and A D in the points F and G.

3. Through F and G, draw F H and G I parallel to A B, cutting H I at the points H and I.

4. From the points H and I, take any number of equal divisions on the lines H F and I G; from these points draw lines to A.

5. From B, set the same divisions towards C and D; draw the parallel lines 1 *a*, 2 *b*, 3 *c*, &c., intersecting the former at the points *a*, *b*, *c*; they will be in the curve of the parabola.

OF THE HYPERBOLA.

DEFINITIONS.

1. If B and C are two fixed points, and a rule A B be made movable about the point B, a string A D C, being tied to the other end of the rule, and to the point C, and if the point A is moved round the centre B, towards E, the angle D, of the string A D C, by keeping it always tight and close to the edge of the rule, A B, will describe a curve, D F H G, called an *hyperbola*.

2. If the end of the rule at B was made movable about the point C, the string being tied from the end of the rule A to B, and a curve being described after the same manner, it would be an *opposite hyperbola.*

3. *Foci* are the two points B and C, about which the rule and string revolve.

4. *Transverse axis* is the line I H, terminated by the two curves passing through the foci, if continued.

5. *Centre* is the point M, in the middle of the transverse axis I H.

6. *Conjugate axis* is the line N O, passing through the centre M, and terminated by a circle from H, whose radius is M C, at N and O.

7. *Diameter* is any line V W, drawn through the centre M, and terminated by the opposite curves.

8. *Conjugate diameter to another* is the line drawn through the centre parallel to a tangent with either of the curves, at the extreme of the other diameter, terminated by the curves.

9. *Abscissa* is when any diameter is contained within the curve, terminated by a double ordinate and the curve, then the part within is called the abscissa.

10. *Double ordinate* is a line drawn through any diameter, parallel to its conjugate, and terminated by the curve.

11. *Parameter*, or *latus rectum*, is a line drawn through the focus, perpendicular to the transverse axis, and terminated by the curve.

12. *Asymptotes* are two right lines drawn from the centre M, and the points R S, which are parallel to the conjugate axis N O, and drawn through the end of the transverse axis I H; H R and H S being equal to M N or M O, then M X and M Y are asymptotes.

13. *Equilateral* or *right-angled hyperbola* is when its transverse or conjugate axes are equal.

PROBLEMS.

Plate 10.

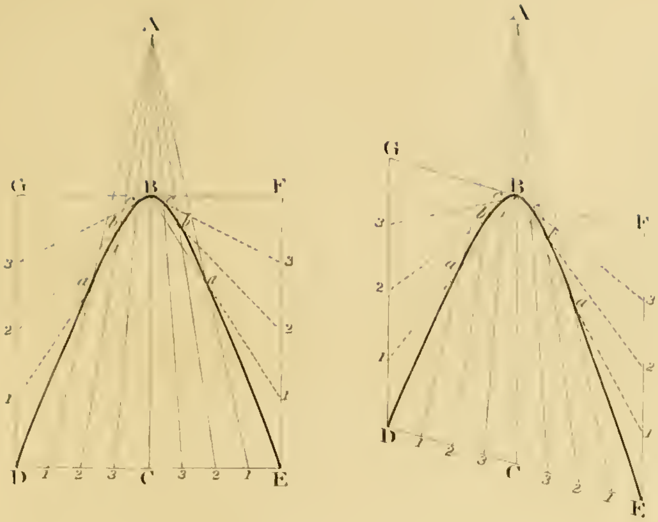
PROBLEM I.

To describe an hyperbola by finding points in the curve having the diameter, or axis A B, its abscissa B C, and double ordinate D E.

1. Through B, draw G F parallel to D E; from D and E, draw D G and E F parallel to B C, cutting G F in F and G.

Pl

PROB. I.



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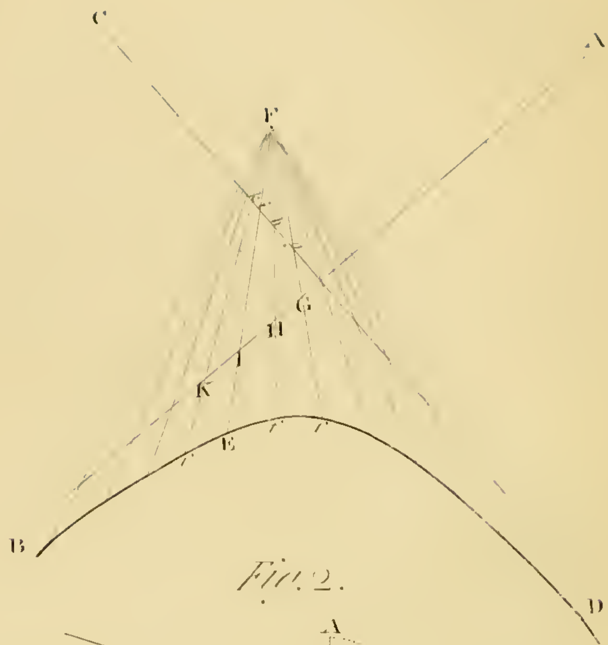
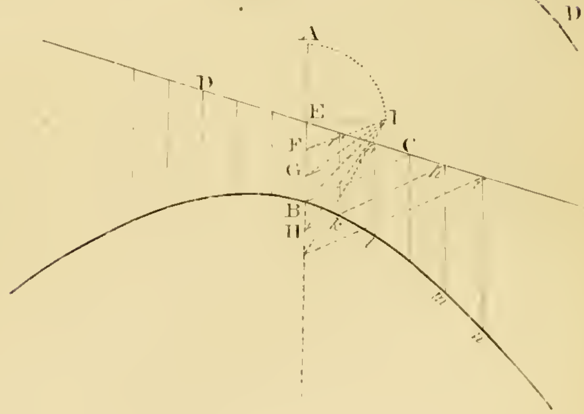


Fig. 2.



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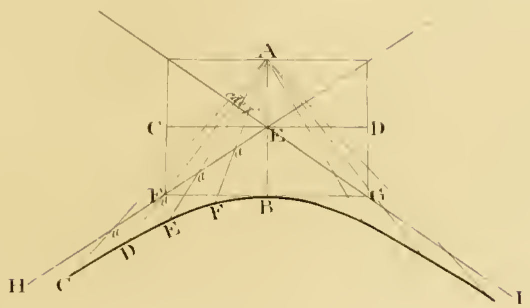

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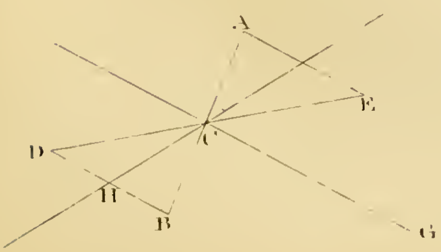

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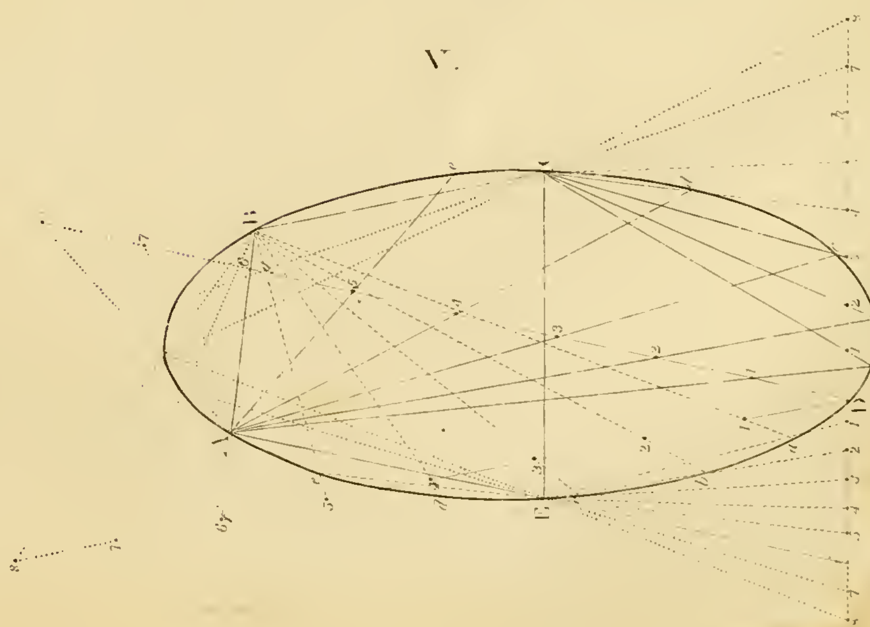
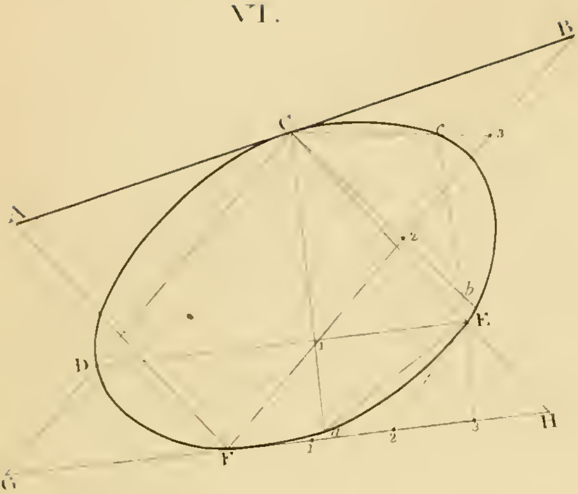
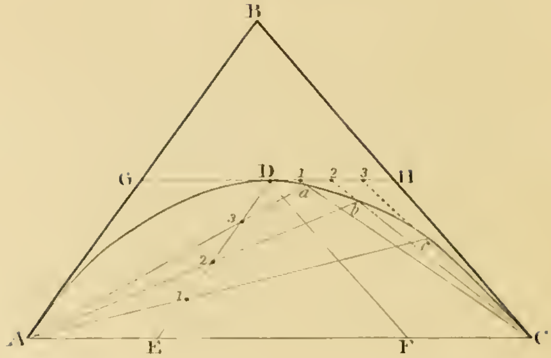


Pl. II

VI.



VII.



PROB. I.

SECTIONS OF SOLIDS.

Of a Cylinder

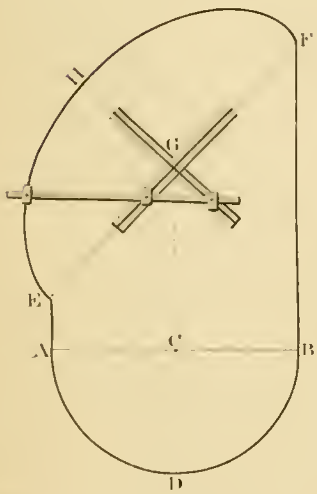


Fig. 2.

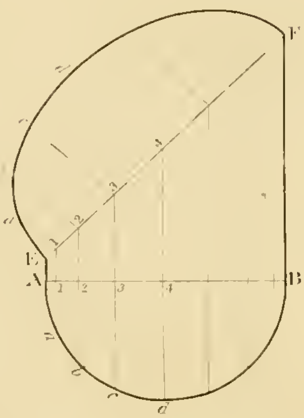
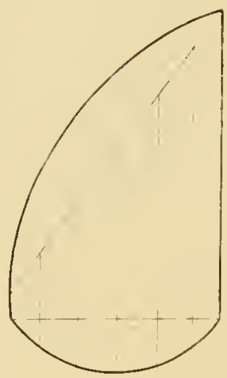


Fig. 3.



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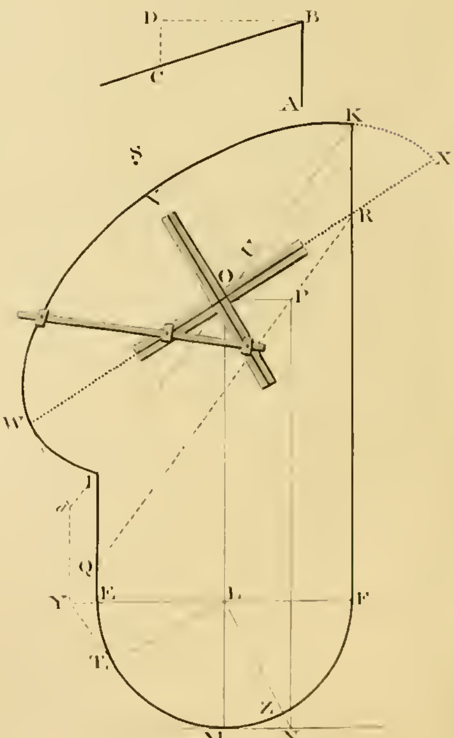

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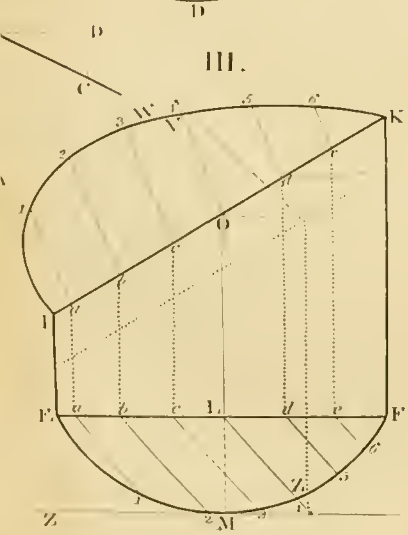


Fig. 2.

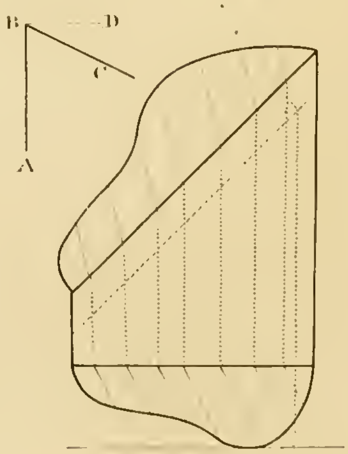
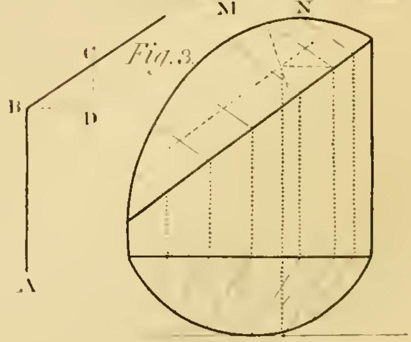


Fig. 3.



2. Divide C D and C E each into any number of equal parts, as four; through the points of division, 1, 2, 3, draw lines to A.

3. Likewise divide D G and E F into the same number of equal parts, viz., four; from the divisions on D G and E F draw lines to B, and a curve being drawn through the intersections at B *a b c* E, will be the hyperbola required.

PROBLEM II.

Given the asymptotes A B, C D, and a point E, in the curve, to describe the hyperbola.

1. Through the given point E, draw any right line E F, cutting the asymptotes in the points *i* and I.

2. Make *i* F equal to I E; from F draw as many lines as you please, cutting the asymptotes in the points *g*, *h*, *i*, *k*, &c., and G, H, I, K, &c.

3. Make G *f*, H *f*, K *f*, &c., respectively, equal to *g* F, *h* F, *k* F, &c., through the points *f*, *f*, *f*, describe a curve, and it is the hyperbola required.

In the same manner may the opposite hyperbola be described.

PROBLEM III.

Given the two conjugate diameters A B and C D, to find any number of points in the curve.

1. Through B draw F G parallel to C D, make B F and B G equal to E C, or E D from E, through F and G draw E H, and E I, the asymptotes.

2. From A draw any lines A C, A D, A E, and A F, cutting the asymptotes at the points *a*, *a*, *a*, &c., and *c*, *d*, *e*, *f*, &c. Make the distances *a* C, *a* D, *a* E, *a* F, &c., equal to A *c*, A *d*, A *e*, and A *f*, &c., then the points C, D, E, F will be in the curve.

Fig. 2. *Another method.*

1. From the centre E, draw E I perpendicular and equal to E A or E B.

2. Join B C, take any number of points, F, G, H, in E B, and draw F *f*, G *g*, H *h* parallel to B C, cutting E C at *f*, *g*, *h*.

3. Through *f*, *g*, *h*, B C, draw *f k*, *g l*, *h m*, *i n*, &c., take the distance F I, and make *f k* equal to it; then take G I, and make *g l* equal to it; in the same manner, find the points *m n*. And if E B and E C are produced indefinitely beyond B and C, and lines be drawn parallel to B E, as before, any number of points beyond will be found in the same manner.

PROBLEM IV.

Given the asymptotes, and a point in the curve, to find two conjugate diameters.

1. From the point B, draw B H D parallel to the asymptote C G. Make H D equal to H B, draw D C E, making C E equal to C D. Make C A equal to C B, then D E is the conjugate to A B.

PROBLEM V.

To describe a conic section through five given points, A, B, C, D, E, provided that all these points are joined by right lines, and that any exterior or angle, formed by these lines, be less than two right angles.

1. Join any four points, A, B, C, E, forming the quadrilateral A B C E.

2. Through the fifth point D, draw D *f* and D *g* parallel to A E and B C, meeting A B, produced both ways at the points *f* and *g*, if necessary.

3. Also, through D, draw *h i* parallel to E C, meeting B C and A E, produced at the points *h* and *i*.

4. Divide D *h*, D *i*, and D *f*, D *g*, into any number of equal parts, as six; likewise divide D F and D G into the same, viz., six.

5. From the point *b*, and through the points 1, 2, 3, 4, 5, in D *i*, draw the lines 1 E, 2 E, 3 E, 4 E, 5 E, cutting the lines B *a*, B *b*, B *c*, B *d*, B *e*, and B *f*, at the points *a*, *b*, *c*, *d*, *e*, draw from B, through 1, 2, 3, 4, 5, in D F, which are all in the curve.

In the same manner, the points between B and D will be found, viz., by drawing lines from the points A and C, through the lines D *g* and D *h*.

And if the lines D *i* and D *f* are produced, and the equal parts, 7, 8, 9, extended upon these lines, you would obtain as many points, *g*, *h*, *i*, &c., between A and B.

Plate 11.

PROBLEM VI.

To describe a conic section to touch a right line A B, in a given point C, to pass through three other points, D, E, and F.

1. Join D C, E C, and D E; through F draw F A and F B parallel to E C and D C, cutting A B at A and B.

2. Through F, draw G H parallel to D E, and produce the sides C D and C E, to cut it at G and H.

3. Divide F G and F H, F A and F B, each into any number of equal parts, as four.

4. From C, through 1, 2, 3, in F H, draw C *a*, C *b*, C *c*, &c.

5. From E, through 1, 2, 3, in F H, draw 1 E, 2 E, 3 E, &c., cutting the former in the points *a*, *b*, *c*, which are in the curve.

In the same manner may points be found in the other side.

PROBLEM VII.

To describe a conic section to touch two right lines, A B and B C, in the points A and C, and to pass through a given point, D.

1. Join the points A and C; through D draw D E and D F parallel to B A and B C.

2. Through D draw G H, parallel to A C, cutting B A and B C in G and H, and divide D G and D H, D E and D F, each into the same number of equal parts.

3. From A, through the points 1, 2, 3, in D E, draw the lines A *a*, A *b*, A *c*.

4. From C, through the points 1, 2, 3, in D H, draw 1 C, 2 C, 3 C, cutting the former in *a*, *b*, *c*, which are in the curve.

In the same manner may points be found between A and D.

SECTIONS OF SOLIDS.

OF A CYLINDER.—DEFINITIONS.

1. A cylinder is a solid, generated by the revolution of a right-angled parallelogram, or rectangle, about one of its sides; and, consequently, the ends of the cylinder are equal circles.

2. Axis is a right line passing from the centres of the two circles which form the ends of the cylinder.

3. If a cylinder is cut by a plane, parallel to a plane passing through its axis, it will be cut in two parts, which are called segments of the cylinder.

4. A segment of a cylinder is comprehended under three planes, and the curve surface of the cylinder; two of these are segments of circles: the other plane is a parallelogram, which is here, for distinction's sake, called the plane of the segment, and the circular segments are called the ends of the cylinder.

5. The two sides of the parallelogram, which is parallel to the axis of the cylinder, are called the sides of the segment of the cylinder, and the other two sides of the parallelogram are chords to the ends of the cylinder.

6. If a cylinder, or segment of a cylinder, stands upon one of its ends, that end on which it stands is called the base.

7. If the segment of a cylinder is cut obliquely by a plane, the intersection of that plane with the plane of the segment is called the chord of the section.

8. The section of a cylinder cut by any plane inclined to its axis is an ellipsis.

This is proved by the writers of conic sections.

PROBLEMS.

Plate 12.

PROBLEM I.

To find the section of a semi-cylinder, cut by a plane at right angles to the plane A B F E, which passes through its axis, making a given angle E F B, with either of the sides B F.

1. Let A D B be the circle of the base, and C its centre.

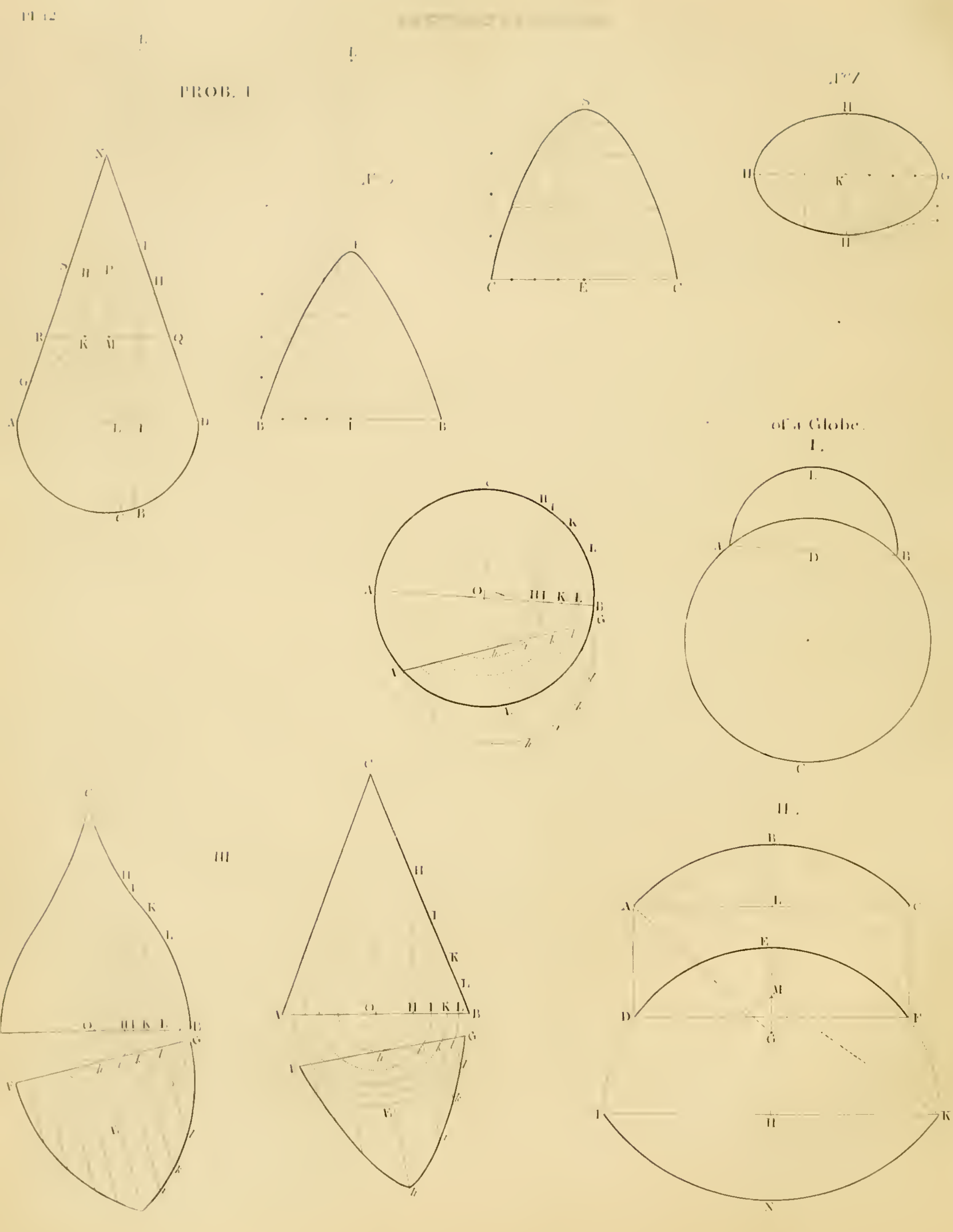
2. Through the centre of the circle C draw G D parallel to F B, cutting the circle of the base in D, and E F at G; from G draw G H perpendicular to E F; make G H equal to C D; then E F is the transverse axis, and G H the semi-conjugate.

Or it may be described by ordinates, as in Fig. 2, taken from the base and transferred to the section, as the figures direct.

In the same manner may any segment be found, viz., by drawing lines parallel to the sides of the plane of the segment till it cut the chords of the section; from these points, draw perpendiculars to the chord; make their several lengths from the chord equal to those of the base corresponding to them; a curve line being drawn through these points, will be the true section of the segment required, as is plainly shown by Fig. 3.

PROBLEM II.

To find the two axes of the section of a semi-cylinder cut by a plane, making a given angle A B C, with the plane E F G H, pass-


PROB. I
of a Globe.

ing through its axis; also in a given direction K I with the side K F.

1. Let E M F be the circle of the base, and L its centre.

2. From the angular point B of the given angle A B C, draw B D perpendicular to B A, and equal to L E or L F, the radius of the base; draw D C parallel to B A, cutting B C at C.

3. Draw Q R, at the distance D C, parallel to I K; through the centre of the circle L draw O M parallel to K F, cutting the circle of the base at M, and I K at O; through the point O draw O P parallel to E F, cutting Q R at P; also through M draw M N parallel to E F, from P draw P S perpendicular to Q R, and P N parallel to O M, cutting M N at N; join L N, cutting the circle at Z; make U S equal to B C, and join O S upon O S; from O, make O V equal to L Z, then O V is the semi-conjugate axis.

4. Through O draw W X perpendicular to O S; draw L T perpendicular to L N, cutting the circle of the base at T; from T, draw T Y parallel to L N, cutting the base F E, produced at Y; from Y, draw Y *a* parallel to O M, cutting K I, produced at *a;* from *a*, draw *a* W parallel to O S, cutting W X at W, making O X equal to O W; then W X is the transverse axis.

PROBLEM III.

To find the section of a segment of a cylinder, by ordinates cut by a plane through a given line I K, in the plane of a segment, making a given angle A B C at I K, with the plane E F K I.

1. Draw the tangent Z M parallel to E F, and draw O M parallel to K F, cutting the tangent at M, and I K at O.

2. Take the distance L M, and make B D perpendicular to the angular point B of the given angle A B C equal to it; proceed as in the last problem; find O V and L Z.

3. Draw any number of lines *a a*, *b b*, *c c*, &c., parallel to O L, cutting the lines I K and E F at the points *a*, *b*, *c*, &c.

4. From the points *a*, *b*, *c*, &c., in I K, draw lines *a* 1, *b* 2, *c* 3, &c., parallel to O V.

5. Through the points *a*, *b*, *c*, in E F, draw lines *a* 1, *b* 2, *c* 3, &c., parallel to L Z, cutting the arc line of the base at 1, 2, 3, &c.

6. Make all the distances *a* 1, *b* 2, *c* 3, &c., from I K, equal to all their corresponding distances, *a* 1, *b* 2, *c* 3, &c., on the base.

7. A curve line being traced through these points, I W K will be the section required.

In the same manner the section of any irregular figure may be found, as is plainly shown by Fig. 2.

Fig. 3 shows how to find the section when the angle A B C is oblique.

OF A CONE.

DEFINITIONS.

1. A cone is a solid figure standing upon a circular base, diminishing to a point at the top, called its *vertex*, in such a manner that, if a straight line be applied from the vertex round the circle of the base, it shall coincide every where with the curve surface of the cone.

2. A right line passing through the cone, from the vertex to the centre of the circle at the base, is called the *axis*.

3. If a cone be cut by a plane not parallel to its base, passing quite through the curve surface, the figure is an *ellipsis*.

4. If a cone be cut by a plane, parallel to a plane touching the curve surface, the section is a *parabola*.

5. If a cone be cut by a plane, parallel to any plane within the cone that passes through its vertex, then the figure is an *hyperbola*.

These three last definitions are proved by the writers of conic sections.

Note. — The cone in the following problem is supposed to be an upright one.

PROBLEM.

Plate 12.

PROBLEM I.

To describe the conic section from the cone.

Note. — A D N is a section of the plane, passing through its axis at right angles with the sections of the ellipsis, parabola, or hyperbola.

For the Ellipsis.

1. Let G H be its transverse axis in the plane A D N; bisect it at K; through K draw R Q parallel to A D.

2. Bisect Q R at M; with the radius M R or M Q describe the semicircle R P G.

3. From K, draw K H perpendicular to Q R, cutting the circle at H; then K H is the semi-conjugate axis, from which the ellipsis may be described as at No. 1.

For the Parabola.

1. Let S E be the axis of the parabola, parallel to the other side, N D.

2. From E, draw E C at right angles to A D, the base, cutting the semicircle at C; then E C is an ordinate or half the base of the parabola, which may be described at No. 2.

For the Hyperbola.

1. Let I F be the height of the hyperbola; produce it till it cut the opposite side A N, produced at L; then F L is the transverse axis.

2. From I, draw I B at right angles to A D; then I B is half the base, which may be described as at No. 3.

NOTE. — The letters are made to correspond at No. 1, 2, and 3, with those of the cone from where they are taken.

OF A GLOBE.

DEFINITIONS.

A globe is a solid figure, and may be supposed to be generated by the revolution of a semicircle about its diameter, which becomes the axis of the globe, and the centre of the semicircle is the centre of the globe.

Corollary 1. Hence all right lines drawn from the centre to the circumference of a globe are equal to one another, for the semicircle touches the surface of the globe in every point as it revolves round.

Corollary 2. The section of a globe by a plane passing through its centre is a circle, whose diameter is equal to the diameter of the generating semicircle.

Corollary 3. Every section of a globe cut by a plane is a circle, for all the lines drawn from the centre to its surface are equal; consequently, the generating semicircle may revolve round any line, as an axis; therefore, every point in the semicircle will generate a circle.

Corollary 4. If a semiglobe is cut at right angles to the plane of its base, the section is a semicircle.

PROBLEMS.

Plate 12.

PROBLEM I.

To find the section of a semiglobe at right angles to the plane A B D, through its centre, and pass through the line A B in that plane.

Bisect A B in D; on D, as a centre, with the radius D A, or D B, describe the semicircle A E B, and it will be the section required.

PROBLEM II.

Given two segments of circles, A B C and D E F, equal or unequal, having their two chords, A C and D F, equal to each other, and the segment A B C being placed upon D F, so that A C shall coincide with D F, and the segment A B C at right angles to D E F, to find the radius of a globe, so that the arc lines A B C and D E F shall be in its surface when the two segments are placed in the above position.

1. Make a rectangle A D F C, so that the opposite sides, A C and D F, will be the bases of the segments A B C and D E F.

2. Find the centres G and H of these segments.

3. Through H draw I K parallel to G F, and complete the semicircle I D E F K.

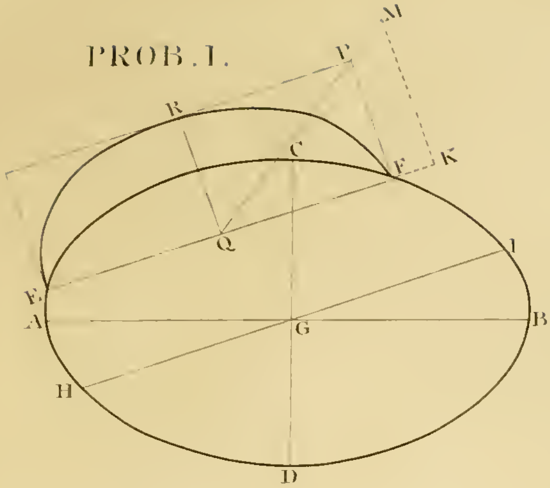
4. Through G or H draw H L parallel to G F, cutting A C and I K at L and H; make H M equal to L G, join M K or M I, and it will be the radius required.

If upon E, as a centre, with the distance M I, or M K, a segment I N K is described, it will be part of the greatest circle that can be drawn in the globe.

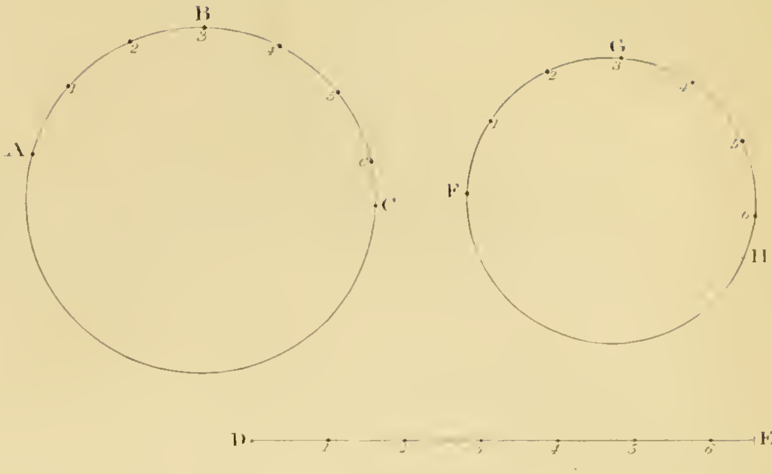
PROBLEM III.

A figure being generated by the revolution of a plain figure, having two perpendicular legs, and the other side being irregular, or straight, or a curve line of any kind, the figure being made to revolve about one of its perpendicular legs. To find the figure of the section, cut any where across the base and right an-

PROB. I.



II.



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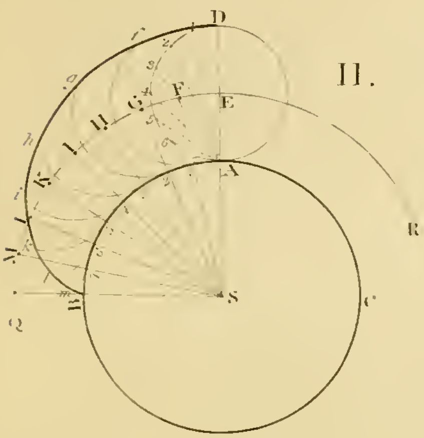
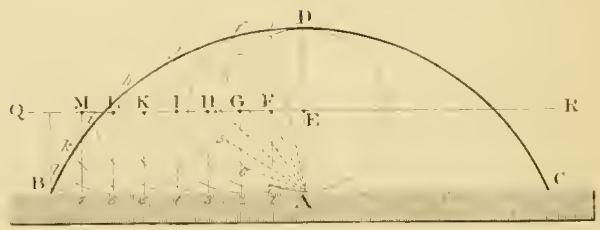
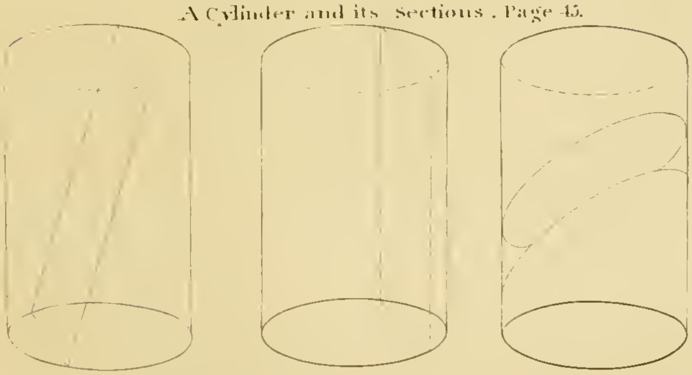


Of a Cycloid and Epicycloid.

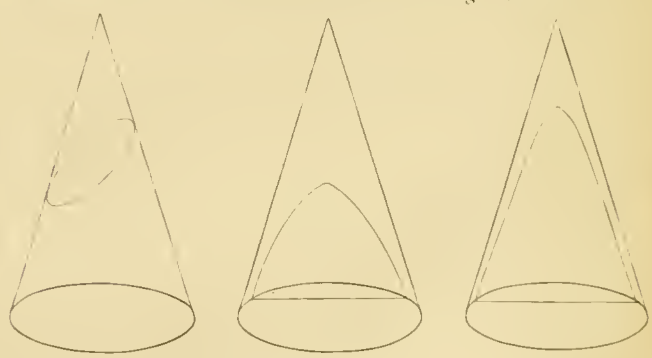
I.



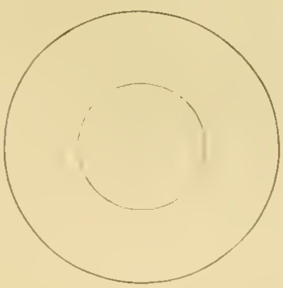
A Cylinder and its Sections. Page 45.



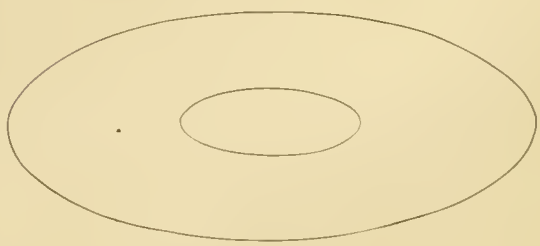
A Cone and its Sections. Page 47.



A Sphere or Globe.



A Spheroid &c.



gles to the plane of the base, having that section which passes through the axis given.

1. Let A F E G B be the circle of the base, and let the section required be cut across F G; also let A B C be a section of the solid passing through the axis.

2. From the centre O, draw the concentric circles H *h*, I *i*, K *k*, L *l*, to cut A B, in the points H, I, K, L, and F G, in the points *h*, *i*, *k*, *l*.

3. Erect perpendiculars to the lines A B and F G, both ways from these points, to cut A C in H, I, K, L.

4. Make the distances *h h*, *i i*, *k k*, *l l*, equal to their corresponding distances H H, I I, K K, L L; a curve being drawn through these points, it will be the section required.

If the given section is triangle, the section is an upright hyperbola.

If the given section is a semicircle, the required section will also be a semicircle; these appear plain by the figures, and in this case there is no tracing required.

OF A SPHEROID.

DEFINITIONS.

1. A spheroid is a solid, generated by the rotation of a semi-ellipsis about the transverse or conjugate axis, and the centre of the ellipsis is the centre of the spheroid.

2. The line about which the ellipsis revolves is called the axis.

3. If the spheroid is generated about the conjugate axis of the semi-ellipsis, then it is called a prolate spheroid.

4. If the spheroid is generated by the semi-ellipsis about the transverse axis, then it is called an oblate spheroid.

Proposition 1.—Every section of a spheroid is an ellipsis, except when it is perpendicular to that axis about which it is generated, in which case it is a circle.

Proposition 2.—All sections of a spheroid parallel to each other are similar figures.

Proposition 3.—If a semi-spheroid is cut by a plane at right angles to the base,* then the section is a semi-ellipsis, and the intersection with the base will be one of its axes; and if a line is drawn perpendicular from the middle of that intersection to the base of the spheroid, to cut its surface, that line will be half the other axis, whether transverse or conjugate.

PROBLEMS.

Plate 13.

PROBLEM I.

Given the base A D B C, which is a section through the longest axis of an oblong spheroid, to find the form of the section, by cutting the base through the line E F, at right angles to its plane.

1. Let A B be the transverse, and C D the conjugate axis of the base; through the centre G draw H I parallel to the given direction E F, cutting the ellipsis at the points H and I.

2. Produce E F towards K; make Q K equal to G H or G I; and erect the perpendicular K M.

3. Make K M equal to C G or G D, and bisect E F at Q, and draw M Q. Erect the perpendicular F P, cutting M Q at the point P, through Q; draw Q R parallel and equal to K M; then Q R will be the semi-conjugate, and E F the transverse axis of the section required, from which the ellipsis may be described by any of the foregoing methods.

PROBLEM II.

To find the length of any arc A B C, of a circle mechanically, very near; or to transfer the same on the circumference of another circle F G H, of a different radius, from a given point F.

1. Take your compass at any small opening, beginning at A, and take the equal parts, 1, 2, 3, 4, 5, 6, on the arc A B C.

2. From D, lay the same number of equal parts on the right line D E, towards E, viz., 1, 2, 3, 4, 5, 6, and from the arc A B C take the remaining part B C, and place it on the right line D E, from 6 to E;

* It is here meant that the base is a section made by a plane, passing through the centre of the spheroid, at right angles to the transverse or conjugate axis of the spheroid.

then will the length of the right line D E be nearly equal to the arc A B C stretched out.

In the same manner may A B C be transferred to the circle F G H, viz., by taking the divisions, 1, 2, 3, 4, 5, 6, and beginning at F, with the same opening of your compass, setting off the divisions, 1, 2, 3, 4, 5, 6, on the arc F G H, and transferring the part 6 C to 6 H, as before; then will the arc F G H be equal to the arc A B C.

OF A CYCLOID OR EPICYCLOID.

DEFINITION.

A cycloid or epicyloid is a figure generated by a circle rolling along the straight edge of a ruler, or another circle at rest, while a point in the circumference describes a figure on the plane called a cycloid or epicycloid.

PROBLEMS.

Plate 13.

PROBLEM I.

To describe a cycloid.

1. Let B C be the edge of a straight ruler; erect A D perpendicular to B C, equal to the diameter of the generating circle; upon the diameter A D describe a circle; through the centre, at E, draw Q R parallel to B C.

2. Divide the semi-circumference D 1 2 3, &c., to A, into equal parts, and lay the same number of equal parts upon the right line A B, from A towards B; from all the divisions on A C erect perpendiculars, cutting Q R at the points F, G, H, &c.

3. With the radius E D or E A, on the points F, G, H, &c., as centres, describe arcs 1 *f*, 2 *g*, 3 *h*, &c.; take the chords A 1, A 2, A 3, &c., from the semicircle; make the distance 1 *f*, 2 *g*, 3 *h*, &c., respectively to them, then these points will be in the curve of the cycloid.

PROBLEM II.

To describe an epicycloid.

1. Let B A C be the edge of the circle round which the other circle is to turn; through the centre S and the point A, in the circumference, draw the right line S D; make A D equal to the diameter of the generating circle.

2. Divide the circumference D 1 2 3, &c., into equal parts, and place them upon the arc A C, from A to 1, 2, 3, &c., to S.

3. With the radius S E, on the centre S, describe the arc Q R; through the centre S and the points 1, 2, 3, &c., draw lines, cutting Q R at F, G, H, &c., and proceed in every other respect, as in the cycloid, and you will get the curve.

SECTION OF PLANES.

Of the Positions of Lines and Planes, and the Properties arising from their Intersections.

DEFINITIONS.

1. A plane is a surface in which a straight line may coincide in all directions.

2. A straight line is in a plane when it has two points in common with that plane.

3. Two straight lines which cut each other in space, or would intersect, if produced, are in the same plane; and two lines that are parallel are also in the same plane.

4. Three points given in space, and not in a straight line, are necessary and sufficient for determining the position of a plane. Hence two planes which have three points common coincide with each other.

5. The intersection of two planes is a straight line.

PROBLEM.

Plate 14.

When two planes A B C D, A B F E, (Fig. 1,) intersect, they form between them a certain angle, which is called the inclination of the two planes, and which is measured by the angle contained by two lines; one drawn in each of the planes, perpendicular to their line of common section.

1. Thus, if the line A F, in the plane A B E F, be perpendicular to A B, and the line A D, in the plane A B C D, be the perpendicular also to A B, then the angle F A D is the measure of the inclination of the planes A B E F, A B C D. When the angle

and the properties arising from the intersection of Planes

Fig. 1.

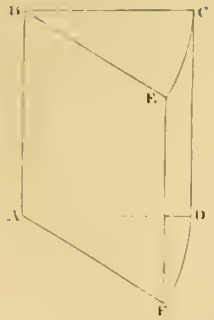


Fig. 2.

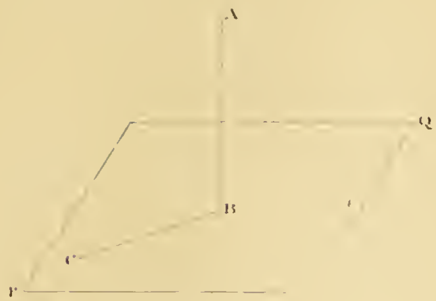


Fig. 3.

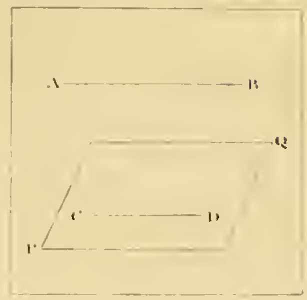


Fig. 4.

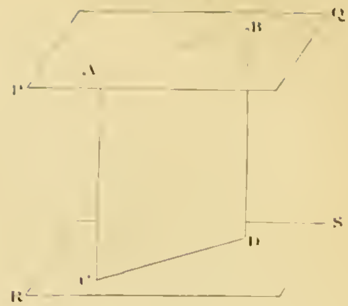


Fig. 5.

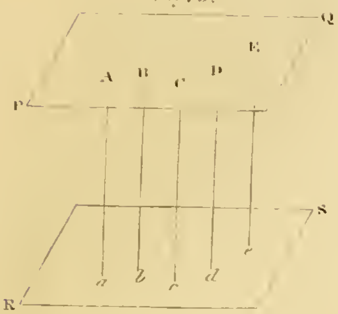
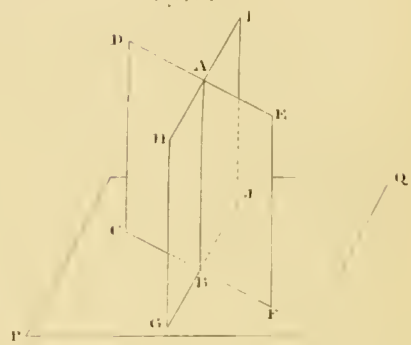


Fig. 6.



The projection of a straight line bent upon a Cylindric surface and the method of drawing a tangent to such a Projection

Fig. 1.

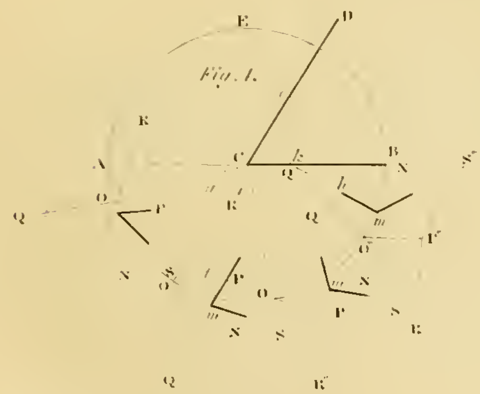


Fig. 2.

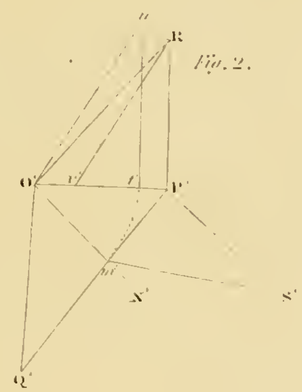


Fig. 3.

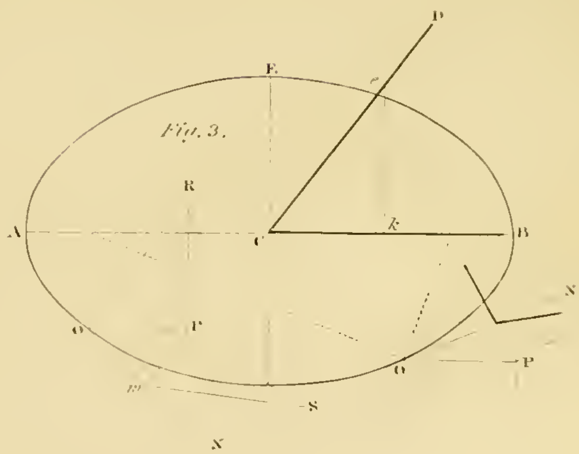


Fig. 4.

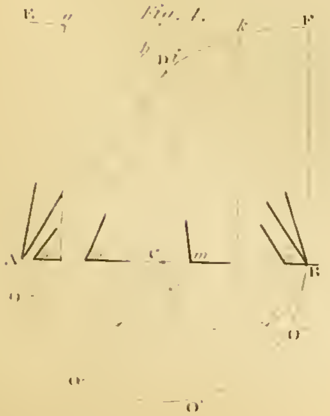


Fig. 5.

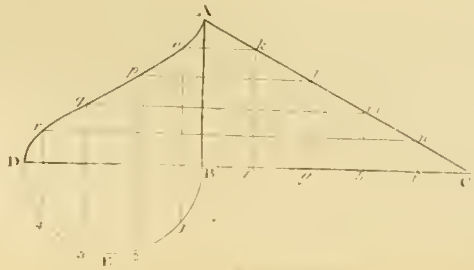
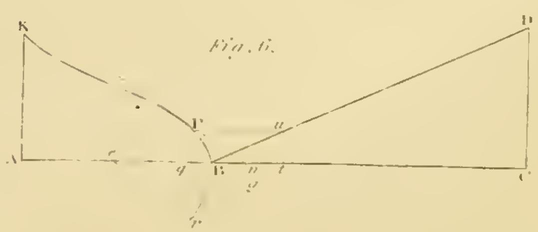


Fig. 6.



F A D is a right angle, the two planes are perpendicular.

2. (Fig. 2.) A line, A B, is perpendicular to a plane P Q, when the line A B is perpendicular to any line B C, in the plane P Q, which passes through the point B, where the line meets the plane. The point B is called the foot of the perpendicular.

3. A line A B (Fig. 3) is parallel to a plane P Q when the line A B is parallel to another straight line C B, in the plane P Q.

4. If a straight line have one of its intermediate points in common with a plane, the whole line will be in the plane.

5. Two planes are parallel to one another when they cannot intersect in any direction.

6. The intersections of two parallel planes with a third are parallel. Thus, in Fig. 4, the lines A B, C D, comprehended by the parallel plane P Q, R S, are parallel.

7. Any number of parallel lines, comprised between two parallel planes, are equal. Thus, Fig. 5, the parallel lines A *a*, B *b*, C *c*, ... , comprised by the parallel planes P Q, R S, are all equal.

8. If two planes C D E F, G H I J, Fig. 6, are perpendicular to a third plane, P Q, their intersection, A B, will be perpendicular to the third plane P Q.

9. If two straight lines be cut by several parallel planes, these straight lines will be divided in the same proportion.

GENERAL APPLICATION OF THE TREHEDRAL TO TANGENT PLANES.

PROBLEM.

Plate 14.

Given the inclination and seat of the axis of an oblique cylinder or cylindroid, to find the angle which a tangent makes at any point in the circumference of the base, with the plane of the base.

1. (Figs. 1, 3, Plate 14.) Let A E B O be the base of the cylinder or cylindroid, C B the seat of the axis, and let B C D be the angle of inclination, and let O be the point where the tangent plane touches the curved surface of the solid.

2. Draw O N a tangent line at the point O in the base, and draw O P parallel to C B. Make the angle P O R equal to B C D, and draw P R perpendicular to P O.

3. Then if the triangle P O R be conceived to be revolved round the line P O, as an axis, until its plane becomes perpendicular to the plane of the circle A E B C, the straight line, O R, will, in this position, coincide with the cylindrical surface, and a plane touching the cylinder or cylindroid at O will pass through the lines O N and O R. Here will now be given the two legs, P O R and P O N, of a right-angled trehedral to find the angle which the hypothenuse makes with the base. Draw P Q perpendicular to O N, intersecting it in *m*, and draw P S perpendicular to P Q. Make P S equal to P R, and join *m* S; then P *m* S is the angle required.

4. The hypothenuse will be easily constructed at the same time, thus: make *m* Q equal to *m* S, and join O Q, then N O Q will be the hypothenuse required.

5. In Fig. 1, the method of finding the angle which the tangent plane makes with the base and the hypothenuse is exhibited at four different points. In the first two points, O from A, in the first quadrant, the tangent planes make an acute angle at each point O; but in the second quadrant, they make an obtuse angle at each point O.

6. Fig. 2 is the second position of the construction from the point A, for finding the angle which the tangent plane makes with the base, and for finding the hypothenuse enlarged; in order to show a more convenient method by not only requiring less space, but less labor, it may be thus described, the two given legs P′ Q′ R′ and P′ O′ N′.

7. Draw P′ *m*′ perpendicular to O′ N′, meeting O N in *m*′. In P′ O′, make P′ *v*′ equal to P′ *m*′, and draw the straight line *v*′ R′, then P′ *v*′ R′ will be the inclination of the tangent plane at the point O.

8. Again: in O′ P′ make O′ *t*′ equal to O′ *m*′, and draw *t*′ *u*′ parallel to P′ R′. From O′, with the radius O′ R′, describe an arc meeting *t*′ *u*′ in *u*′, and draw the straight line O′ *u*′; then *t*′ O′ *u*′ is the hypothenuse.

9. For since P′ S′ is equal to P′ R′, and P′ *v*′ equal to P′ *m*′, and the angles *m*′ P′ S′ and *v*′ P′ R′ are right angles; therefore, the triangle *v*′ P′ R′ is equal to the triangle *m*′ P′ S′, and the remaining angles of the one equal to the remaining angles of the other, each to each; hence the angle P′ *v*′ R′ is equal to the angle P′ *m*′ S′.

10. Again: because $O' t'$ is equal to $O' m'$, and $O' Q'$ is equal to $O' R'$, and $O' n'$ is also equal to $O' R'$, therefore $O' n'$ is equal to $O' Q'$; and since the angles $O' t' n'$ and $O' m' Q'$ are each a right angle, therefore the two right-angled triangles have their hypothenuses equal to each other, and have also one leg in each equal to each other; therefore the remaining side of the one triangle is equal to the remaining side of the other, and therefore, also, the angles which are opposite to the equal sides are equal; hence the angle $P' O' n'$ is equal to $N' O' Q'$.

11. By considering this construction by the transposition of the triangles, the whole of the angles which the tangent planes make at a series of points O, in figures 1 and 3, their hypothenuses may be all found in one diagram, as in Fig. 4.

12. Thus, in Fig. 4, if the angles A C O, A C O′ A C O″, A C O‴, be respectively equal to A C O, A C O′, A C O″, A C O‴, Fig. 1, and in Fig. 4, the semicircle A O′ B be described, and if C D be drawn perpendicular to A B, and the angles C A D, C B D, be made equal to B C D, Fig. 1, then each half of Fig. 4, being constructed as in Fig. 2, the angles at m m' m'' m''' will be respectively equal to the angles P m S, P′ m' S′, Q″ m'' S″, Q″ m''' S″, in Fig. 1.

Also, in Fig. 4, the angles C A E, C A g, C A h, C B i, C B k, C B F will be the hypothenuses at the points A, O, O′, O″, O‴, B, in Fig. 1.

We may here observe, Fig. 1, that the angles which the tangent planes make with the plane of the base in the first quadrant are acute; and those in the second quadrant are obtuse; and those in the second quadrant are the supplements of the angles P m S; and, moreover, that all the angles which constitute the hypothenuses of the trehedral are all acute, whether in the first quadrant or the second quadrant of the semicircle A O B.

SECTIONS

On the projection of a straight line bent upon a cylindric surface, and the method of drawing a tangent to such a projection.

Plate 14.

PROBLEM I.

Given the development of the surface of the semi-cylinder, and a straight line in the development, to find the projection of the straight line on a plane passing through the axis of the cylinder, supposing the development to incase the semi-cylindric surface.

Fig. 5. Let A B C be the development of the cylindric surface, B C being the development of the semi-circumference, and let A C be the straight line given.

Produce C B to D, making B D equal to the diameter of the cylinder. On B D, as a diameter, describe the semicircle B E D, and divide the semicircular arc B E D into any number of equal parts, at 1, 2, 3, &c., and its development B C into the same number of equal parts, at the points f, g, h, &c. Draw the straight lines $f\,k$, $g\,l$, $h\,m$, &c., parallel to B A, meeting A C at the points k, l, m, &c.; also parallel to B A draw the straight lines 1 o, 2 p, 3 q, &c., and draw $k\,o$, $l\,p$, $m\,q$, &c., parallel to C D; and the points o, p, q, &c., are the projections or seats of the points k, l, m, &c., in the development of the straight line A C.

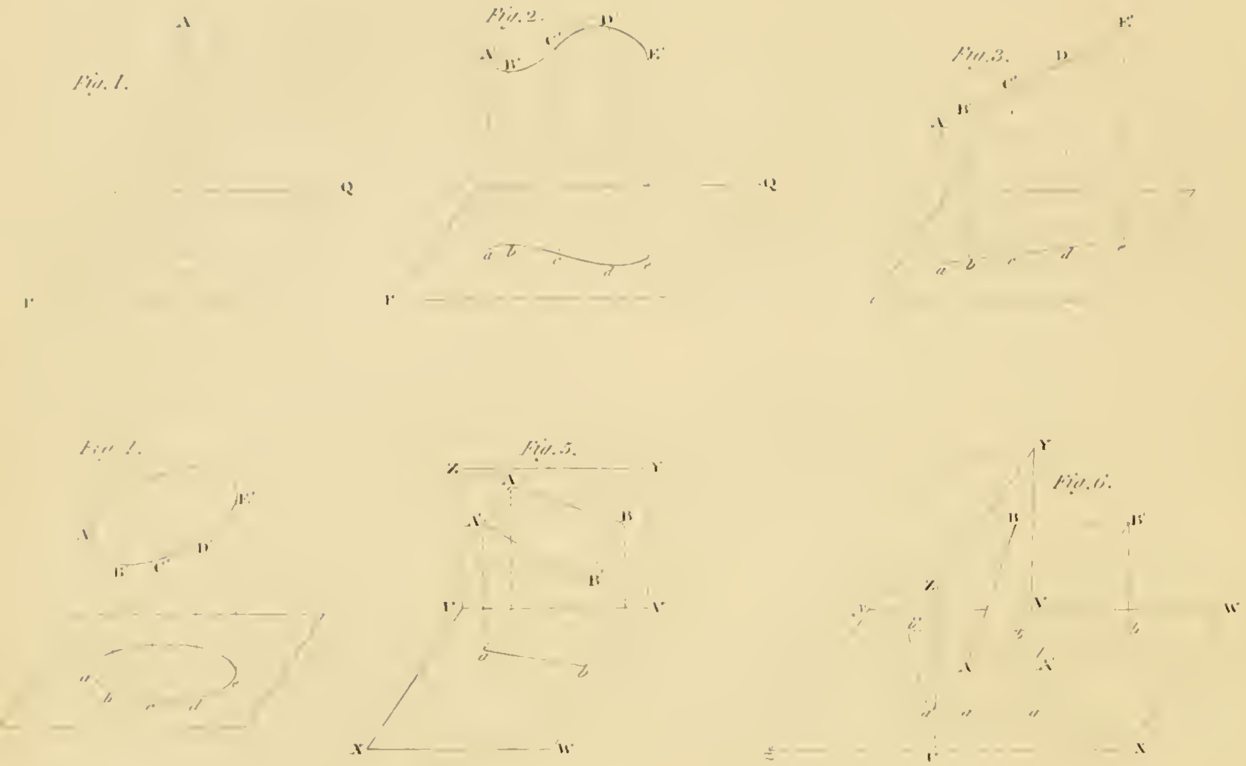
The projection of a screw is found by this method: B D may be considered as the diameter of the cylinder from which the screw is formed; and the angle B A C the inclination of the thread, with a straight line on the surface; or B C A the inclination of the thread with the end of the cylinder. The same principle also applies to the delineations of the hand rails of stairs, and in the construction of bevel bridges, of which we shall treat in a subsequent part of this work.

PROBLEM II.

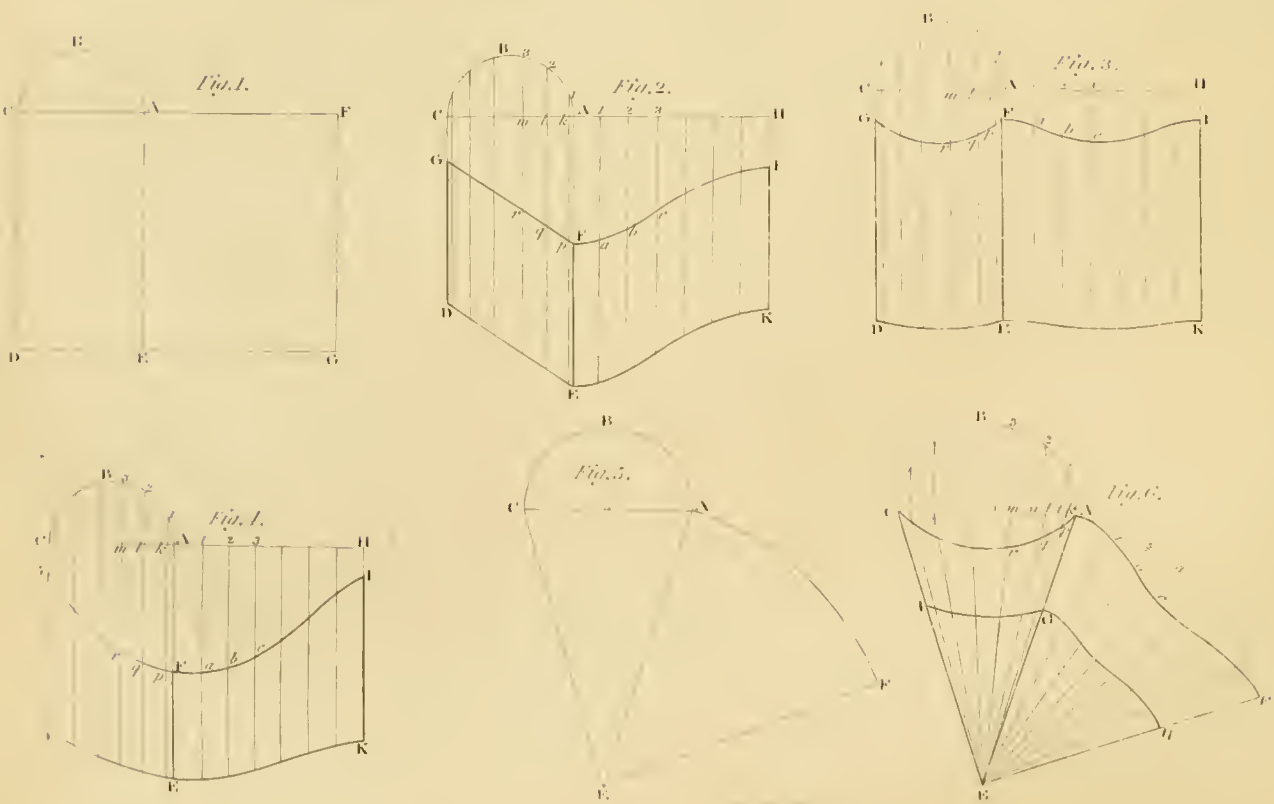
Given the entire projection of a helix or screw, in the surface of a semi-cylinder, and the projection of a circle in that surface perpendicular to the axis, upon the plane passing through the axis, to draw a tangent to the curve at a given point.

Fig. 6. Let B P K be the projection of the helix or screw, and B A the projection of the circumference of a circle, and since this circle is in a plane perpendicular to the plane of projection, it will be projected into a straight line A B, equal to the diameter of the cylinder.

On A B, as a diameter, describe the semicircle



On the developements of the surfaces of Solids.



A r B, and draw P r perpendicular to, and intersecting, A B in q, join the points c r, and produce c r to f.

Produce A B to C, so that B C may be equal to the semicircular arc B r A. Draw C D perpendicular to B C, and make C D equal to A K, and draw the straight line B D; then B D will be the development of the curve line B P K.

Draw P u parallel to A C, meeting B D in u, and draw u t perpendicular to B C. Draw r g perpendicular to c r, and make r g equal to B t. Draw g n perpendicular to A C, meeting B C in n, and draw the straight line n P; then n P will touch the curve at the point P.

Or the tangent may be drawn independent of B C D, thus: Draw P r perpendicular to A B, and r g a tangent at r. Make r g equal to the development of r B, and draw g n perpendicular to B C′, meeting B C in n, and join n P, which is the tangent required.

PRELIMINARY PRINCIPLES OF PROJECTION.

PROBLEM.

Plate 15.

If from a point A′, Fig. 1, in space, a perpendicular A′ a be let fall to any plane P Q whatever, the foot a of this perpendicular is called the *projection* of the point A′ upon the plane P Q.

If, through different points A′, B′, C′, D′,....Figs. 2, 3, 4, of any line A′, B′, C′, D′, ... whatever in space, perpendiculars A′ a, B′ b, C′ c, D′ d, . . . be let fall upon any plane P Q whatever, and if through a, b, c, d, ... the projections of the points A′, B′, C′, D′, in the plane P Q, a line be drawn, the line thus drawn will be the projection of the line A′ B′ C D′ . . . . given in space.

If the line A′ B′ C′ D′ . . . . Fig. 3, be straight, the projection a b c d . . . . will also be a straight line; and if the line A′ B′ C′ D′ . . . . Fig. 2, be a curve not in plane perpendicular to the plane P Q, the curve a b c d . . . . which is the projection of the curve A′ B′ C′ D′, ... in space, will be of the same species with the original curve, of which it is the projection. Hence, in this case, if the original curve A′ B′ C′ D′ . . . . be an ellipse, a parabola, an hyperbola, &c., the projection a b c d . . . . will be an ellipse, a parabola, an hyperbola, &c. The circle and the ellipse being of the same species, the projected curve may be a circle or ellipse, whether the original be a circle or ellipse, as in Fig. 4.

The plane in which the projection of any point, line, or plane figure is situated is called the plane of projection, and the point or line to be projected is called the primitive.

The projection of a curve will be a straight line when the curve to be projected is in a plane perpendicular to the plane of projection. Hence the projection of a plane curve is a straight line.

If a curve be situated in a plane which is parallel to the plane of projection, the projection of the curve will be another curve equal and similar to the curve of which it is the projection.

The projection upon a plane of any curve of double curvature whatever is always a curve line.

In order to fix the position and form of any line whatever in space, the position of the line is given to each of two planes which are perpendicular to each other; the one is called the horizontal plane, and the other the vertical plane; the projection of the line in question is made on each of these two planes, and the two projections are called the two projections of the line to be projected.

Thus we see, in Fig. 5, where the parallelogram U V W X represents the horizontal plane, and the parallelogram U V Y Z represents the vertical plane; the projection a b of the line A′ A′ in space upon the horizontal plane U V W X is called the *horizontal projection;* and the projection A B, of the same line upon the vertical plane U V Y Z, is called the *vertical projection.*

The two planes upon which we project any line whatever are called the planes of projection.

The intersection U V of the two planes of projection, is called the ground line.

When we have two projections a b, A B of any line A B′ in space, the line A′ B′ will be determined by erecting to the planes of projection the perpendiculars a A′, b B′ . . . A A′, B B′ . . . through the projections a, b, ... A, B, ... of the original points A′, B′. . . . . . of the line in question. For the perpendiculars a A′, A A′ erected from the projections a, A of the same point A′ will intersect each other in space in a point A′, which will be one of these in the line ir

question. It is clear that the other points must be found in the same manner as this which has now been done.

When we have obtained the two projections of a line in space, whether immediately from the line itself or by any other means whatever, we must abandon this line in order to consider its two projections only, since, when we design a working drawing, we operate only upon the two projections of this line that we have brought together upon one plane, and we no longer see any thing in space.

However, to conceive that which we design, it is absolutely necessary to carry by thought the operations into space from their projections. This is the most difficult part that a beginner has to surmount, particularly when he has to consider at the same time a great number of lines in various positions in space.

The perpendicular A′ *a*, Fig. 5, let fall from any point A whatever in space upon the plane X V of projection, is called the projectant of the point A′ upon this plane. Moreover, the perpendicular distance between the point A′ and the horizontal plane X V, is called the projectant upon the horizontal plane, or simply the horizontal projectant; and the perpendicular distance A′ A between the original point A′ and the vertical plane U Y, is called the projectant upon the vertical plane, or simply the vertical projection.

We shall remark, so as to prevent any mistake, that the horizontal projectant A′ *a* is the perpendicular let fall from the original point upon the horizontal plane, and that the vertical projectant is the perdicular let fall from that point upon the vertical plane. Hence the horizontal projectant is parallel to the vertical plane, and is equal to the distance between the original point and the horizontal plane; and the vertical projectant is parallel to the horizontal plane, and is equal to the distance between the original point and the vertical plane.

We may remark, that if through *a*, Fig. 6, the horizontal projection of the point A′, we draw a perpendicular *a* to U V, the ground line, this perpendicular *a* will be equal to the measure of the vertical projectant A′ A; consequently, the distance of the point A′ to the vertical plane is equal to the distance between *a*, its horizontal projection, and U V, the ground line measured in a perpendicular to U V. In like manner, if through A, the vertical projection of the point A′, we draw a perpendicular A *a* to U V, the ground line, this perpendicular A *a* will be equal to the measure of the horizontal projectant A *a;* consequently, the distance of this point A′ to the horizontal plane is equal to the distance between A, its vertical projection, and U V, the ground line measured in a perpendicular to U V.

To these very important remarks we shall add one which is not less so. Two perpendiculars, *a* a, Fig. 6, A a, being let fall from the projections *a*, A to the same point A′ upon the ground line U V, will meet each other in the same point a, of the said ground line U V.

If we now wished the two projections of a point A′, Fig. 6, or of any line A′ B′ whatever, to be upon one or the same plane, it is sufficient to imagine the vertical plane U V Y Z to turn round the ground line U V in such a manner as to be the prolongation of the horizontal plane U V W X; for it is clear that this plane will carry with it the vertical projection A or A B of the point, or of the line in question. Moreover, we see, and it is very important, that the lines A a, B b, perpendicular to the ground line U V, will not cease to be so in the motion of the plane U V Y Z; and as the corresponding lines *a* a, *b* b, are also perpendiculars to the ground line U V, it follows that the lines a *a*′, b *b*′, will be the respective prolongation of the lines *a* a, *b* b.

Hence it results, when we consider objects upon a single plane, the projections *a* A, of a point A′ in space, are necessarily upon the same perpendicular A *a* to the ground line U V.

It is necessary to call to mind that the distance A a, measures the distance from the point in space to the horizontal plane, (the point A being the vertical projection of this point,) and that the line *a* a measures the distance from the same point in space to the vertical plane.

It follows, that if the point in space be upon the horizontal plane, its distance with regard to this last-named plane will be zero or nothing, and the vertical A a will be zero also. Moreover, the vertical projection of this point will be upon the ground line at the foot a, of the perpendicular *a* a, let fall upon the ground line, from the horizontal projection *a* of this point.

Again: if the point in space be upon the vertical plane, its distance, in respect of this plane, will be zero, the horizontal *a* a will be zero, and the horizontal projection of the point in question will be the foot

a, of the perpendicular A a, let fall upon the ground line from the vertical projection A, of this point.

In general, we suppose that the vertical projection of a point is above the ground line, and that the horizontal projection is below; but from what has been said, it is evident that, if the point in space be situated below the horizontal line, its vertical projection will be below the ground line; for the distance from this point to the horizontal plane cannot be taken from the base line to the top, but from the top to the base with respect to its plane.

So if the point in space be situated behind the vertical plane, its horizontal projection will be above the ground line; from which we conclude, —

1. If the point in question be situated above the horizontal plane, and before the vertical plane, its vertical projection will be above, and its horizontal projection below, the ground line.

2. If the point be situated before the vertical plane, and below the horizontal plane, the two projections will be above the ground line.

3. If the point be situated above the horizontal plane, but behind the vertical plane, the two projections will be above the ground line.

4. Lastly. If the point be situated above the horizontal plane, and behind the vertical plane, the vertical projection will be below, and the horizontal projection above, the ground line.

The reciprocals of these propositions are also true.

If a line be parallel to one of these planes of projection, its projection upon the other plane will be parallel to the ground line. Thus, for example, if a line be parallel to a horizontal plane, its vertical projection will be parallel to the ground line; and if it is parallel to the vertical plane, its horizontal projection will be parallel to the ground line.

Reciprocally, if one of the projections of a line be parallel to the ground line, this line will be parallel to the plane of the other projection. Thus, for example, if the vertical projection of a line be parallel to the ground line, this line will be parallel to the horizontal plane, and *vice versa*.

If a line be at any time parallel to the two planes of projection, the two projections of this line will be parallel to the ground line; and reciprocally, if the two projections of a line be parallel to the ground line, the line itself will be at the same time parallel to the two planes of projection.

If a line be perpendicular to one of the planes of projection, its projection upon this plane will only be a point, and its projection upon the other plane will be perpendicular to the ground line. Thus, for example, if the line in question be perpendicular to the horizontal plane, its horizontal projection will be only a point, and its vertical projection will be perpendicular to the ground line.

Reciprocally, if one of the projections of a straight line be a point, and the projection of the other perpendicular to the ground line, this line will be perpendicular to the plane of projection upon which its projection is a point. Thus the line will be perpendicular to the horizontal plane, if its projection be the given point in the horizontal plane.

If a line be perpendicular to the ground line, the two projections will also be perpendicular to this line. The reciprocal is not true; that is to say, that the two projections of a line may be perpendicular to the ground line, without having the same line perpendicular to the ground line.

If a line be situated in one of the planes of projection, its projection upon the other will be upon the ground line. Thus, if a line be situated upon a horizontal plane, its vertical projection will be upon the ground line; and if this line were given upon the vertical plane, its horizontal projection would be upon the ground line.

Reciprocally, if one of the projections of a line be upon the ground line, this line will be upon the plane of the other projection. Thus, for example, if it be the vertical projection of the line in question, which is upon the ground, this line will be upon the horizontal plane; if, on the contrary, it were upon the horizontal projection of this line which was upon the ground line, this line would be upon the vertical plane.

If a line be at any time upon the two planes of projection, the two projections of this line would be upon the ground line, and the line in question would coincide with this ground line. Reciprocally, if the two projections of a line were upon the ground line, the line itself would be upon the ground line.

If two lines in space are parallel, their projections upon each plane of projection are also parallel. Reciprocally, if the projections of two lines are parallel on each plane of projection, the two lines will be parallel to one another in space.

If any two lines whatever in space cut each other, the projections of their point of intersection will be

upon the same perpendicular line to the ground line, and upon the points of intersection of the projections of these lines. Reciprocally, if the projections of any two lines whatever cut each other in the two planes of projection in such a manner that their points of intersection are upon the same perpendicular to the ground line, these two lines in question will cut each other in space.

The position of a plane is determined in space when we know the intersections of this plane with the planes of projection.

The intersections A B, A C, of the plane in question, with the planes of projections, are called the *traces* of this plane.

The trace situated in the horizontal plane is called the *horizontal trace*, and the trace situated in the vertical plane is called the *vertical trace*.

A very important remark is, that the two traces of a plane intersect each other upon the ground line.

If a plane be parallel to one of the planes of projection, this plane will have only one trace, which will be parallel to the ground line, and situated in the other plane of projection. Reciprocally, if a plane has a trace parallel to the ground line, this plane will be parallel to the plane of projection, which does not contain this trace. Thus: —

1. If a plane be parallel to the horizontal plane, this plane will not have a horizontal trace, and its vertical trace will be parallel to the ground line. Likewise, if a plane be parallel to the vertical plane, this plane will not have a vertical trace, and its horizontal trace will be parallel to the ground line.

2. If a plane has only one trace, and this trace parallel to the ground line, let it be in the vertical plane; then the plane will be parallel to the horizontal plane. So if the trace of the plane be in the horizontal plane, and parallel to the ground line, the plane will be parallel to the vertical plane.

If one of the traces of a plane be perpendicular to the ground line, and the other trace in any position whatever, this plane will be perpendicular to the plane of projection in which the second trace is. Thus, if it be a horizontal trace which is perpendicular to the ground line, the plane will be perpendicular to the vertical plane of projection; and if, on the contrary, the vertical trace be that which is perpendicular to the ground line, then the plane will be perpendicular to the horizontal plane.

Reciprocally, if a plane be perpendicular to one of the planes of projection, without being parallel to the other, its trace upon the plane of projection, to which it is perpendicular, will be perpendicular to any position whatever, and the other trace will be perpendicular to the ground line. Thus, for example, if the plane be perpendicular to the vertical plane, the vertical trace will be perpendicular to the ground line. The reverse will also be true, if the plane be perpendicular to the horizontal plane.

If a plane be perpendicular to the two planes of projection, its two traces will be perpendicular to the ground line. Reciprocally, if the two traces of a plane are in the same straight line perpendicular to the ground line, this plane will be perpendicular to both the planes of projection.

If the two traces of a plane are parallel to the ground line, this plane will be also parallel to the ground line. Reciprocally, if a plane be parallel to the ground line, its two traces will be parallel to the ground line.

When a plane is not parallel to either of the planes of projection, and one of its traces is parallel to the ground line, the other trace is also necessarily parallel to the ground line.

If two planes are parallel, their traces in each of the planes of projection will also be parallel. Reciprocally, if on each plane of projection the traces of the two planes are parallel, the planes will also be parallel.

If a line be perpendicular to a plane, the projections of this line will be in each plane of projection perpendicular to the respective traces in this plane. Reciprocally, if the projections of a line are respectively perpendicular to the traces of a plane, the line will be perpendicular to the plane.

If a line be situated in a given plane by its traces, this line can only intersect the planes of projection upon the traces of the plane which contains it. Moreover, the line in question can only meet the plane of projection in its own projection. Whence it follows, that the points of meeting of the right line, and the planes of projection, are respectively upon the intersections of this right line, and the traces of the plane which contains it.

If a right line, situated in a given plane by its traces, is parallel to the horizontal plane, its horizontal projection will be parallel to the horizontal trace of the given plane, and its vertical projection will be parallel to the ground line. Likewise, if the right

line situated in a given plane by its traces is parallel to the vertical plane, its vertical projection will be parallel to the vertical line of the plane which contains it, and its horizontal projection will be parallel to the ground line.

Reciprocally, if a line be situated in a given plane by its traces, and, for example, its horizontal projection be parallel to the horizontal trace of the given plane, this line will be parallel to the horizontal plane, and its vertical projection will be parallel to the ground line. Likewise, if the vertical projection of the line in question be parallel to the vertical trace of the given plane, this line will be parallel to the vertical plane, and its horizontal projection will be parallel to the ground line.

SECTION

On the Developments of the Surfaces of Solids.

PROBLEMS.

Plate 15.

PROBLEM I.

To find the development of the surface of a right semi-cylinder.

Fig. 1. Let A C D E be the plane passing through the axis. On A C, as a diameter, describe the semicircular arc A B C. Produce C A to B, and make A F equal to the development of the arc A B C. Draw F G parallel to A E, and E G parallel to A F; then A F G E is the development required.

PROBLEM II.

To find the development of that part of a semicylinder contained between two perpendicular surfaces.

Figs. 2, 3, 4. Let A B C D E be a portion of a plane passing through the axis of the cylinder, C D and A E being sections of the surface, and let D E and F G be the insisting lines of the perpendicular surface; also, let A C be perpendicular to A E and C D. On A C, as a diameter, describe the semicircular arc A B C. Produce C A to H, and make A H equal to the development of the arc A B C. Divide the arc A B C and its development each into the same number of equal parts, at the points 1, 2, 3.

Though the points 1, 2, 3, &c., in the semicircular arc, and in its development, draw straight lines parallel to A E, and let the parallel lines through 1, 2, 3, in the arc A B C, meet F G in p, q, r, &c., and A C in k, l, m, &c. Transfer the distances kp, lq, mr, &c., to the development upon the lines 1 a, 2 b, 3 c, &c. Through the points F, a, b, c, &c., draw the curve line F c 1. In the same manner draw the curve line E K; then F E I K will be the development required.

PROBLEM III.

To find the development of the half surface of a right cone, terminated by a plane passing through the axis.

Fig. 5. Let A C E be the section of the cone passing along the axis A E, and C E the straight lines which terminate the conic surface, or the two lines which are common to the section C A E and the conic surface; and let A C be the line of common section of the axal plane and the base of the cone.

On A C, as a diameter, describe a semicircle, A B C. From E, with the radius E A, describe the arc A F, and make the arc A F equal to the semicircular arc A B C, and join E F; then the sector A E F is the development of the portion of the conic surface required.

PROBLEM IV.

To find the development of that portion of a conic surface contained by a plane passing along the axes, and two surfaces perpendicular to that plane.

Fig. 6. Let A C E be the section of the cone along the axis, and let A C and G I be the insisting lines of the perpendicular surfaces. Find the development A E F, as in the preceding problem. Divide the semicircular arc A B C, and the sectorial arc A F, each into the same number of equal parts at the points 1, 2, 3, &c. From the points 1, 2, 3, &c., in the semicircular arc, draw straight lines, 1 k, 2 l, 3 m, &c., perpendicular to A C. From the points k, l, m, &c., draw straight lines, k E, l E, m E, &c., intersecting the curve A C in p, q, r, &c. Draw the straight lines pt, qu, rv, &c., parallel to one side, E C meeting A C in the points t, u, v, &c. Also from the

points 1, 2, 3, in the sectorial arc A F, draw the straight lines 1 E, 2 E, 3 E, &c. Transfer the distances *pt*, *qu*, *rv*, &c., to 1 *a*, 2 *b*, 3 *c*, &c.; then, through the points A, *a*, *b*, *c*, &c., draw the curve A *c* F, and A *c* F is one of the edges of the development, and by drawing the other edge, the entire development, A G H, will be found.

Note. — This treatise on the subject of Geometry we have thought best to insert in the form in which it was first written. It is a system in a degree peculiar to its author, and it is, without doubt, the production of a laborious research; and although the same conclusions would, in some cases, be arrived at by the more direct process of demonstration used at the present day, yet, from its extent and completeness, we have concluded, as a whole, that no part could be materially changed for the better without seriously intruding upon the theories of our venerable author, and that, too, at the expense of interfering with his style of writing, which will at once be recognized as the original. We will state here, that we have endeavored, as much as possible, to preserve every idea that he has advanced, and that, too, in his own language. — Editors.

PROJECTION OF PRISMS.

In the annexed definitions and problems, the student will find enough to give him a correct and sufficiently perfect idea of the nature and importance of this useful branch of science; and he will also find occasion to apply the geometrical principles, a knowledge of which he is presumed to have acquired from the preceding pages of the present work.

DEFINITIONS.

1. When straight lines are drawn according to a certain law from the several parts of any figure or object cut by a plane, and by that cutting or intersection describe a figure on that plane, the figure so described is called the projection of the other figure or object.

2. The lines taken altogether, which produce the projection of the figure, are called a *system of rays.*

3. When the system of rays are all parallel to each other, and are cut by a plane perpendicular to them, the projection on the plane is called the *orthography of the figure proposed.*

4. When the system of parallel rays is perpendicular to the horizon, and projected on a plane parallel to the horizon, the orthographical projection is then called the *ichnography*, or plan of the figure proposed.

5. When the rays of the system are parallel to each other and to the horizon, and if the projection be made on a plane perpendicular to those rays and to the horizon, it is called the elevation of the figure proposed.

[In this kind of projections, the projection of any particular point or line is sometimes called the seat of that point or line, on the plane of projection.]

6. If a solid be cut by a plane passing quite through it, the figure of that part of the solid which is cut by the plane is called a *section.*

7. When any solid is projected orthographically upon a plane, the outline or boundary of the projection is called the *contour* or profile of the projection.

Note. — Although the term *orthography* signifies, in general, the projection of any plane which is perpendicular to the projecting rays, without regarding the position of the plane on which the object is projected, yet writers on projection substitute it for elevation, as already defined, by which means it will be impossible to know when we mean that particular position of orthographical projection which is made on a plane perpendicular to the horizon.

Axiom. — If any point, line, or plane of any original figure or object touch the plane on which it is to be projected, the place where it touches the projecting plane is the projection of that point, line, or plane of the original figure or object.

Proposition. — The orthographical projection of a line which is parallel to the plane of projection is a line equal and parallel to its original.

PROBLEMS.

Plate 16.

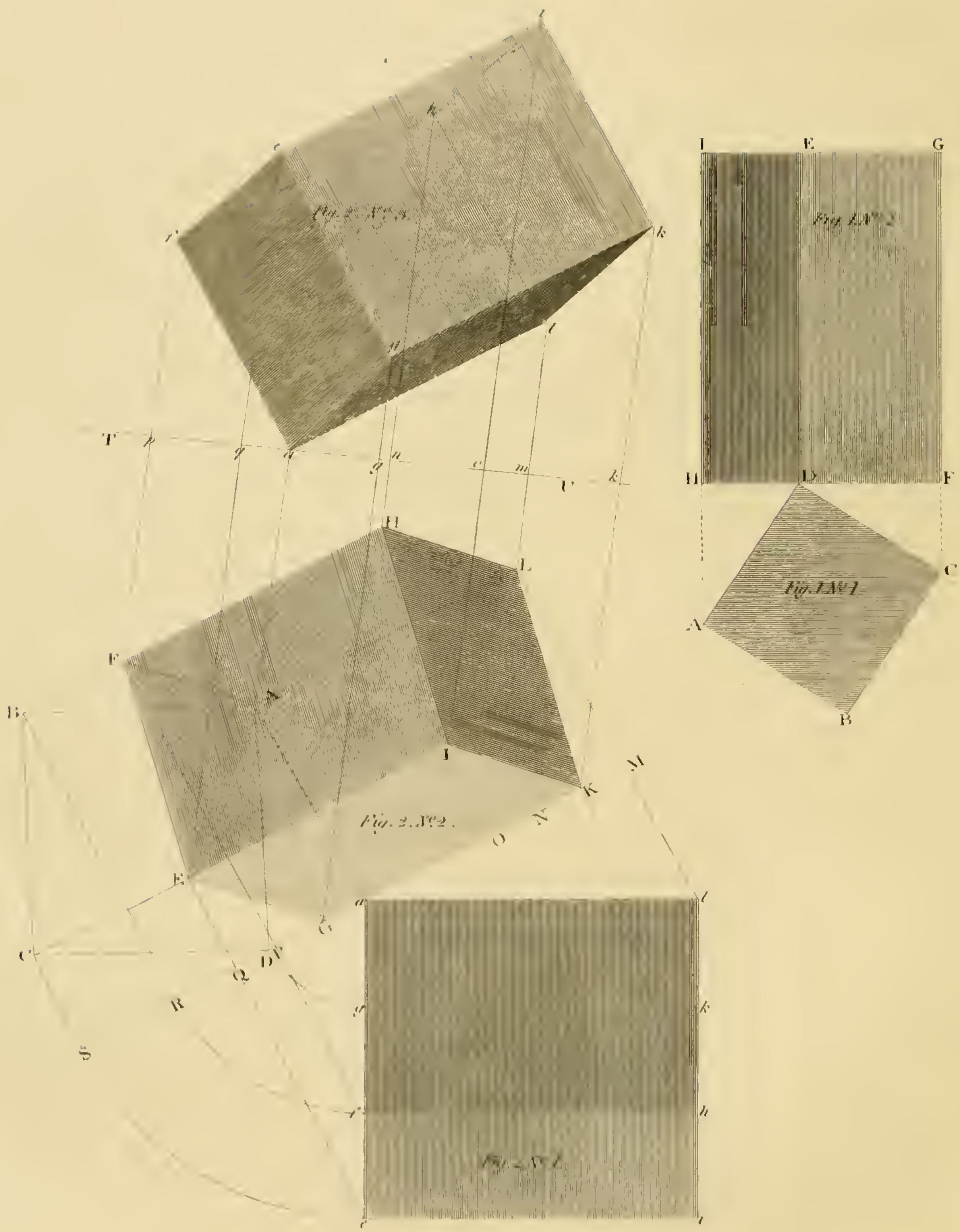
PROBLEM I.

To project the elevation of a prism standing on a plane perpendicular to the projecting plane; given, the base of the prism and its position to the projecting plane.

Fig. 1. Let A B C D, No. 1, be the base of the prism; let H F be the intersection of the projecting plane, with the plane on which the prism stands.

Draw lines from every angle of the base, cutting

Pl. 16



H F at H, and F will be the projection of the points A and C; the angle D, touching H F at D, is its projection.

From each of the points H, D, F, in No. 2, draw the lines H I, D E, and F G, each perpendicular to H F; make D E equal to the height of the prism; through E draw I G, cutting H I and F G at I and G, which will give the projection sought.

PROBLEM II.

To project the ichnography and elevation of a square prism, to rest upon one of its angles upon a given point A, in the plane, on which the ichnography is to be described; given the ichnography A L, of an angle, which the two under planes make with each other; the angle M *a l*, which the angle of the solid makes with its ichnography A L; the intersection A *a* of one of its ends with the plane of the ichnography; the angle D A *a*, which one side of the end makes at A, with the intersection A *a* of that end; also given one of the sides of the ends, and the length of the prism.

Fig. 2. At the given point A, with the intersection A *a*, make an angle *a* A D, equal to the angle which one of the sides of the end makes with A *a;* make A D equal to one of the sides of the end; then on A D construct the square A B C D; through the angles of the square B, C, D, draw lines B H, C I, and D M, parallel to A L; then at the point *a*, in the right line D M, make an angle M *a l*, with *a* M, equal to the angle of the solid, whose projection is A L, with A L; make *a l* equal to the length of the solid; through the points *a* and *l*, No. 1, draw the lines *a e* and *l i* perpendicular to *a l;* through the points B and C, No. 2, draw B R and C S parallel to A *a*, cutting D M, produced at R and S; on *a*, as a centre, with the distances *a* D, *a* R, and *a* S, describe arcs P *g*, R *f*, and S *e*, cutting *a e*, No. 1, at *g*, *f*, *e;* through the points *g*, *f*, *e*, draw the lines *g k*, *f h*, and *e i*, parallel to *a l*, and No. 1 will be completed, which will be the projection of the prism on a plane parallel to A L. Through the points *g*, *f*, *e*, draw the lines *e* E, *f* F, and *g* G, perpendicular to D M, or A L, cutting D E, C I, and B H, respectively, at G, E, F; also through the points *l*, *k*, *h*, *i*, draw the lines *l* L, *k* K, *h* H, and *i* I, likewise parallel to A L, cutting A L, G M, B H, and C I, respectively, at the points L, K, H, and I; join E F, E G, and H I, I K, K L, L H, then will the planes E F H I, E I K L, and H I K L represent the ichnography of the upper sides of the solid; and if F A and A G be joined, then will F A G E, F A L H, and G A L K represent the sides of the solid next to the plane of projection. Then to project the elevation on a plane whose intersection is T U, from F, E, G, A, H, I, K, and L, that is, from all the points in the ichnography representing the solid angles, draw the lines F *f*, E *e*, G *g*, A *a*, H *h*, I *i*, K *k*, and L *l*, perpendicular to the intersection T U, cutting T U at *p*, *q*, *a*, *g*, *o*, *m*, and *k;* make *p f*, *q e*, *g g*, *n h*, *o i*, *m l*, and *k k*, at No. 3, respectively, equal to P *f*, Q *e*, G *g*, N *h*, O *i*, M *l*, and K *k*, at No. 1; then join *f a*, *a g*, *g e*, *e f*; *e i*, *i k*, *k g*, *k l*, and *l a;* and *f a g e*, *g e i k*, *g k l a* will be the elevations of the outside planes of the solid; and by joining *f h*, and *h i*, *f h i e*, *f h l a*, and *i h l k* will be the elevations of the planes of the solid next to the plane on which the elevation is projected.

SHADOWS.

This is one of the most interesting branches of architectural science; or perhaps it may, with more propriety, be termed a branch of geometry, for it is almost entirely dependent on, and governed by, geometrical principles.

From a knowledge of it the architect is enabled to draught his plans, and to give them their true effect, or representation of light and shade; to construct his windows in order to receive light to the best advantage, &c., &c. The art of keeping a proper gradation of light and shade on objects, according to their several distances, colors, and other circumstances, is of the utmost consequence to the artist.

THE EFFECT OF DISTANCE ON THE COLOR OF OBJECTS.

The art of giving a due diminution or degradation to the strength of the light and shade and colors of objects, according to the different distances, the quantity of light which falls on their surfaces, and the medium through which they are seen, is called *keeping*.

1. When objects are removed to a great distance from the eye, the rays of light which they reflect will be less vivid, and the color will become more diluted, and tinged with a faint bluish cast, by reason of the great body of air through which they are seen.

2. In general, the shadows of objects, according as they are more remote from the eye, will be lighter, and the light parts will become darker; and at a certain distance the light and shadow are not distinguishable from each other, for both will seem to terminate in a bluish tint of the color of the atmosphere, and will appear entirely lost in that color.

3. If the rays of light fall upon any colored substance, the reflected rays will be tinged with the color of that substance.

4. If the colored rays be reflected upon any object, the color of that object will then be compounded of the color of the reflected rays and the color of the object; so that the color of the object which receives the reflection will be changed into another color.

5. From the closeness or openness of the place where the object is situated, the light, being much more variously directed, as in objects which are surrounded by buildings, will be more deprived of reflection, and, consequently, will be darker than those which have no other objects in their vicinity, except the surrounding objects are so disposed as to reflect the rays of light upon them.

6. In a room, the light being more variously directed and reflected than abroad in the open air, (for every aperture gives an inlet to a different stream,) which direction is various, according to the place and position of the aperture, whereby every different side of the room, and even the same side in such a situation, will be variously affected with respect to their light, shade, and colors, from what they would in an open place when exposed to rays coming in the same direction.

Some original colors naturally reflect light in a greater proportion than others, though equally exposed to the same degrees of it, whereby their degradation at different distances will be different from that of other colors which reflect less light.

The art of keeping a degradation of light and shade on objects, according to their several distances, colors, and other circumstances, is of the utmost consequence to the artist.

In orthographical projections, where equal and similar objects stand in the same position to the plane of projection, they will be represented similar, and of an equal magnitude at every distance from that plane; and, consequently, planes which are parallel to each other would not appear to have any distance, so that the representation of any number of objects, at different distances from each other, would be entirely confused, and no particular object could be distinguished from the others; but, by a proper attention to the art of *keeping*, every object will be distinct and separate, and their respective distances and colors from each other will be preserved. But though a proper degradation of light and shade ought to be preserved, according to the respective distances of objects from each other, artists in general take too great liberties with nature: we frequently see in the drawings of architects the art of keeping carried to so great an extreme as to render their performances ridiculous.

DEFINITIONS.

1. A body which is continually emitting a stream of matter from itself, and thereby rendering objects visible to our sense of seeing, is called a *luminary;* such as the *sun*, or any other body producing the same effect.

2. The stream of matter which is emitted from the luminary is called *light.*

3. A substance or body which light cannot penetrate is called an *opaque body.*

4. If a space be deprived of light by an opaque body, it is called a *shade.*

5. The whole or part of any surface on which a shade is projected is called a *shadow.*

6. A body which will admit of light to pass through it is called a *transparent substance.*

7. A line of light emitted from the luminary is called a *ray.*

Proposition 1. — The rays of light, after issuing from the luminary, proceed in straight lines.

Proposition 2. — If the rays of light fall upon a reflecting plane, the angle made by any incident ray, and a perpendicular to the reflecting plane, is called the angle of incidence, and will be equal to the angle that its reflected ray will make with the same perpendicular, called the angle of reflection; these two propositions are known from experiment.

Proposition 3. — If the rays of light fall upon any curved surface, whether concave or convex, or mixed of the two, the angle of reflection will still be equal to the angle of incidence.

Proposition 4. — Any uneven reflecting surface, whose parts lie in various directions, will reflect the rays of the sun in as many different directions.

Demonstration. — If any ray fall upon a part of the surface which is perpendicular to that ray, it will be reflected in the same line as the incident ray; but the more or less any part of the surface is inclined to a ray, falling upon that part of the surface, the greater or less angle will the reflected ray make with the incident ray. For imagine a perpendicular to be erected to that part of the surface where any incident ray impinges on the surface, it is evident that the measure of the angle of incidence is equal to the obtuse angle made by the incident ray, and the reflecting surface at the impinging point made less by a right angle; but the angle of reflection is equal to the angle of incidence; wherefore it follows that the whole angle formed by the incident and reflected rays is double of the angle of incidence; and, consequently, a reflecting surface, whose parts lie in various directions, will reflect the sun's rays in as many directions.

Corollary. — Hence appears the reason why objects and their parts become visible to our sight when immersed in shade.

SEAT OF THE SUN'S RAYS.

DEFINITIONS.

1. If a given straight line pass through or cut a given plane, and if an imaginary plane be supposed to pass through any two points in the straight line, perpendicular to the other plane, the angle made by the intersection of the two planes and the given straight line is called the inclination or altitude of the given line on the given plane.

2. The intersection of the planes is called the seat of the given line on the given plane.

Corollary. — The angle made by a ray of light, and the seat of that ray, is the angle of the sun's in clination.

3. If on the surface of any solid there be any point or points in the surface where the sun's rays fall perpendicular, this point or points which the sun's rays fall perpendicular to are called points of light.

4. If on the surface of any solid there be any line drawn upon that surface, and if the line so drawn upon the surface be lighter than any other line that can be drawn upon the said surface, then the line first drawn is called the line of light.

5. If the sun's rays fall upon any solid, and if a line or lines be drawn on the surface of the solid where the sun's rays are a tangent, or upon the place or places of the surface which divide the dark side from the light side, then the line or lines so described are called a line or lines of shade.

6. If the sun's rays be parallel to any plane, that plane to which they are parallel is called a plane of shade.

PROBLEMS.

PROBLEM I.

Given the ichnography and elevation of a prism, whose sides stand perpendicular to the horizon, and whose ichnography is a figure of

any kind, regular or irregular; given the seat of the sun on the ichnography, also on the elevation, and the intersection of the plane of the elevation with the plane of the ichnography; the representation of the point being likewise given on the elevation, and also on the ichnography, to determine the representation of the shadow on the elevation.

Through the representation of the given point in the plane of the ichnography draw a line parallel to the seat of the sun's rays on that plane, and produce it till it cut the intersection; from that point on the elevation draw a line perpendicular to the intersection; then through the representation of the given point on the elevation draw a line parallel to the sun's seat on the elevation, cutting the line that was drawn perpendicular to the intersection, and that point will be the representation of the shadow on the elevation.

Plate 17.

PROBLEM II.

Given the altitude and seat of the sun on the horizon and the intersection of a plane, making a given angle with the horizon; to find the seat and altitude of the sun on the other plane.

Fig. 1. Let D F be the seat of the sun on the horizon, and D F G the angle of the sun's elevation, E F the intersection of the plane with the horizon, and A B C the angle which that plane is to make with the horizon.

Produce D F till it meet E F in F; through any point D, in the seat D F, draw D G perpendicular to D F, cutting F G in G; also, through D draw D K perpendicular to E F, cutting E F in E; through D draw D I perpendicular to D K; make the angle D E H equal to the given angle A B C; make D I equal to D G; through I draw I H perpendicular to E H, cutting it in H; make E K equal to E H; join K F; from K make K L perpendicular to K F; from K make K L equal to H I; join L F; then will I K be the seat of the sun on the other plane, and K F L will be the angle of the altitude.

If the plane K E F stands perpendicular to the horizon, as in Fig. 2, the operation will be more simple, as follows, the same letters standing for the same things: —

Make E K equal to D G; join K F; draw K L, as before, and make K L equal to D E; join L F; then will K F be the seat of the sun on the horizon, and K F L be the seat of the altitude.

Plate 18.

PROBLEM III.

Given the ichnography A B C D E F G H I K, and elevation L M N O, of an upright prism, whose base or ichnography is a regular polygon, and the seat of the sun's rays on the base, to determine the various degrees of light and shade on the different sides of the prism.

Fig. 1. Let P Q, in the ichnography, be the seat of the sun; and if it cut C D perpendicular, then will C D be the lightest side of the prism; the sides D E and C B will be a small degree darker, as P Q is more inclined to D E and C B; and in general, according as the sides recede on each side of C D, they will be continually darker until they become wholly deprived of light; then suppose the sun's ray to touch the side G H, then G H will be the plane of shade, or that side where the light will end.

Much in the same manner may the different degrees of shade be found on the surface of a cylinder, as in Fig. 2, where A B C D is the ichnography, and G H I K the elevation; that is, if B P be the direction of the sun's rays, cutting the ichnography in B, then will B be the lightest place; and it will be continually darker and darker in each side of the point B, until it arrives at the point C, where the ray touches the side of the cylinder, and there the light will end and the darkness begin.

PROBLEM IV.

To represent the boundaries of light and shade on the elevation of a cone illumined by the sun, given the angle that any ray of light takes with the base of the cone; also to determine the line of light, or that place on the surface that will be the lightest.

Figs. 3 and 4. Let A E D be the elevation of the cone, and let F I L G be the ichnography or base of the cone; let F L be the seat of any ray in a plane

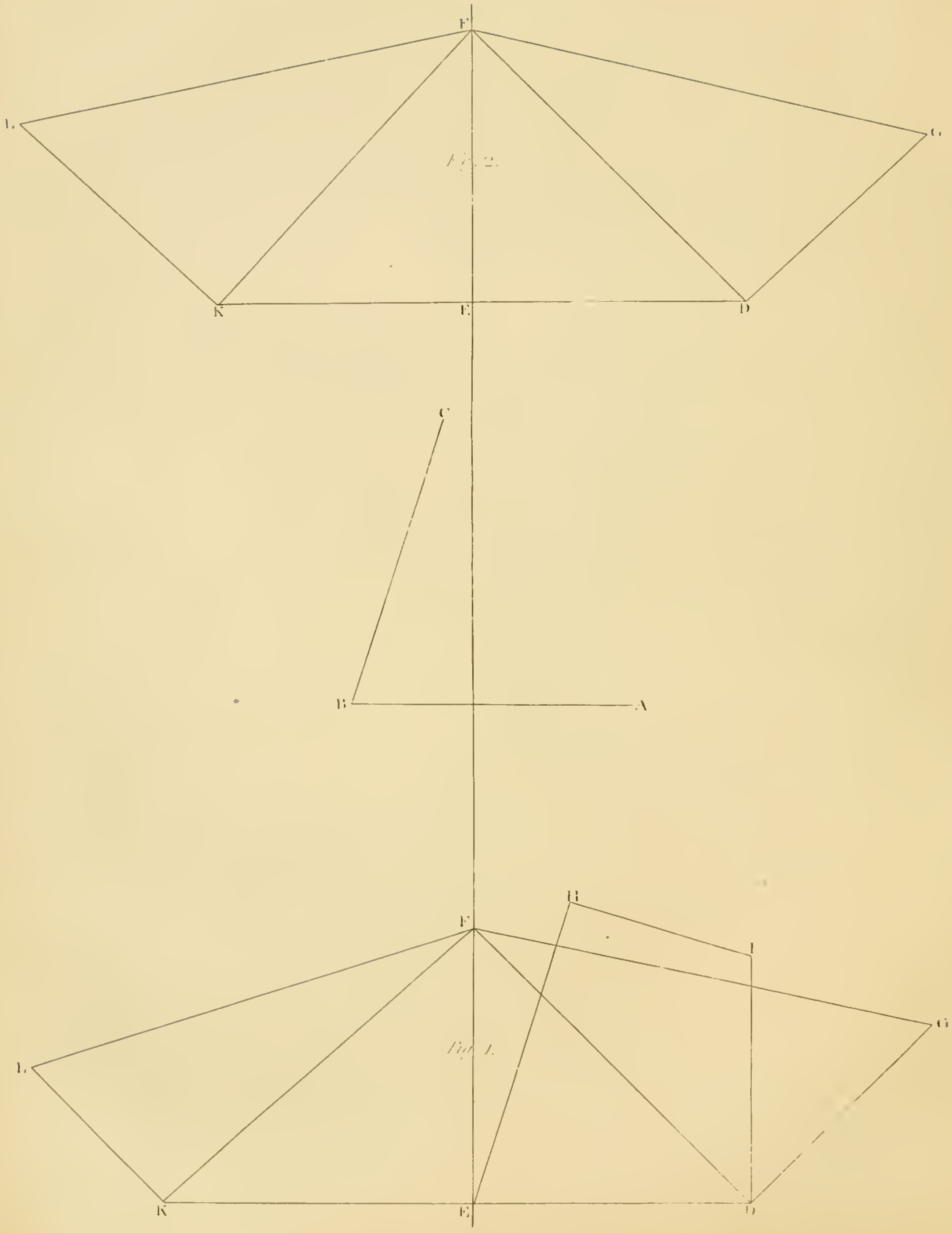

F
L
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Fig. 2.
K
E
D
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Fig. 1.
L
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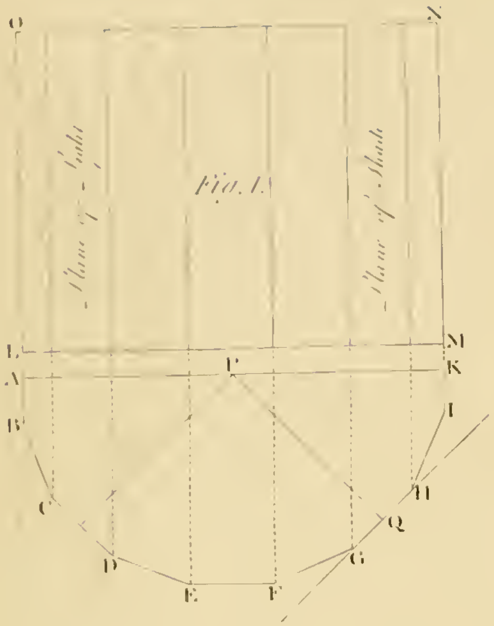


Fig. 1.
Plane of Light
Plane of Shade
O N L M A P K B I C H Q D G E F

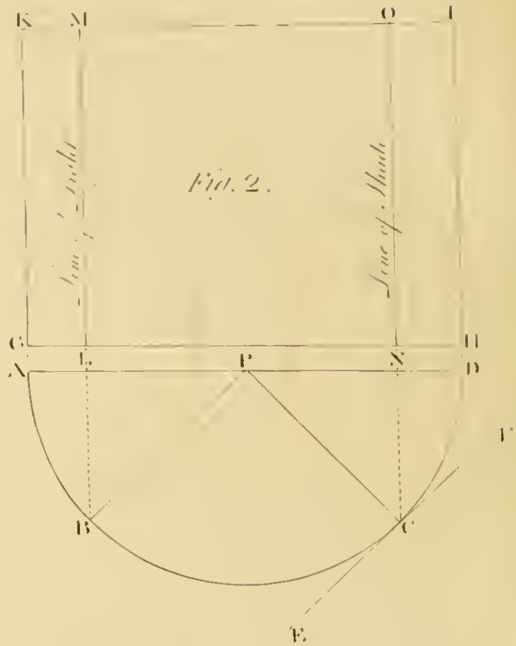


Fig. 2.
Line of Light
Line of Shade
K M O I G H A L P N D F B C E

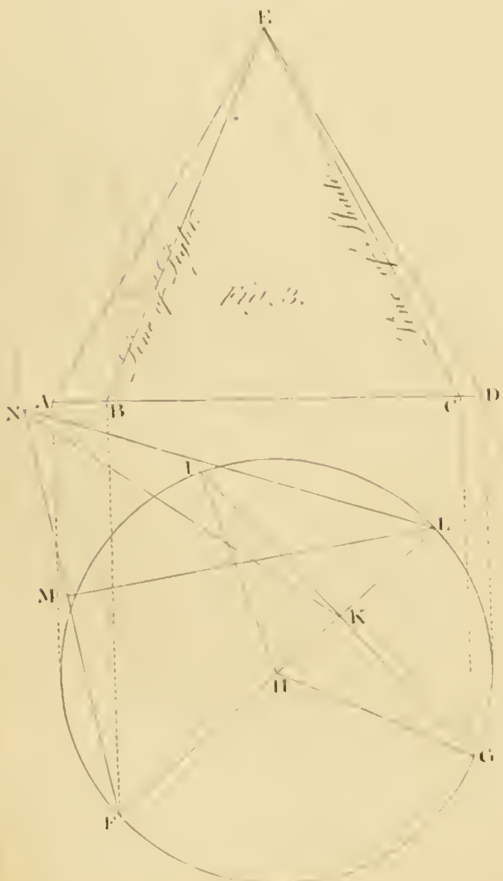


Fig. 3.
Line of Light
Line of Shade
E N A B C D I L M K H G F

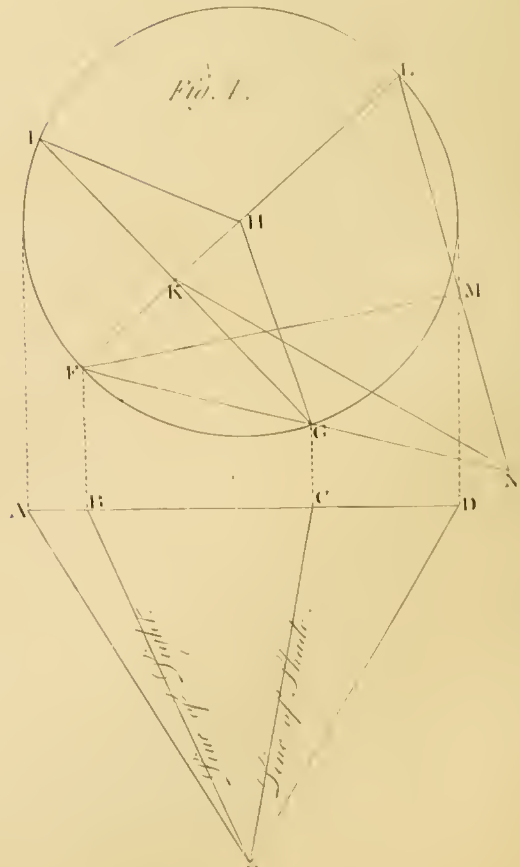


Fig. 4.
Line of Light
Line of Shade
L I H K M F G N A B C D E

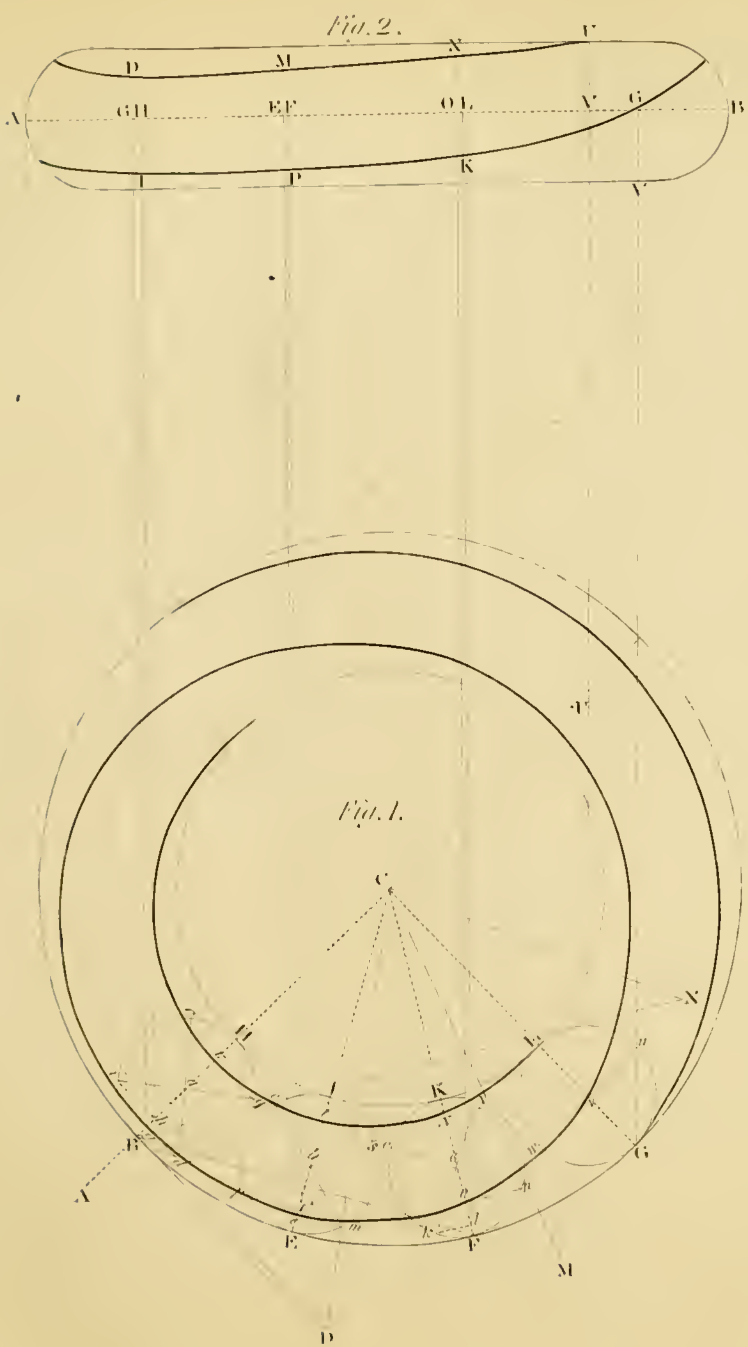


Fig. 2.
Fig. 1.

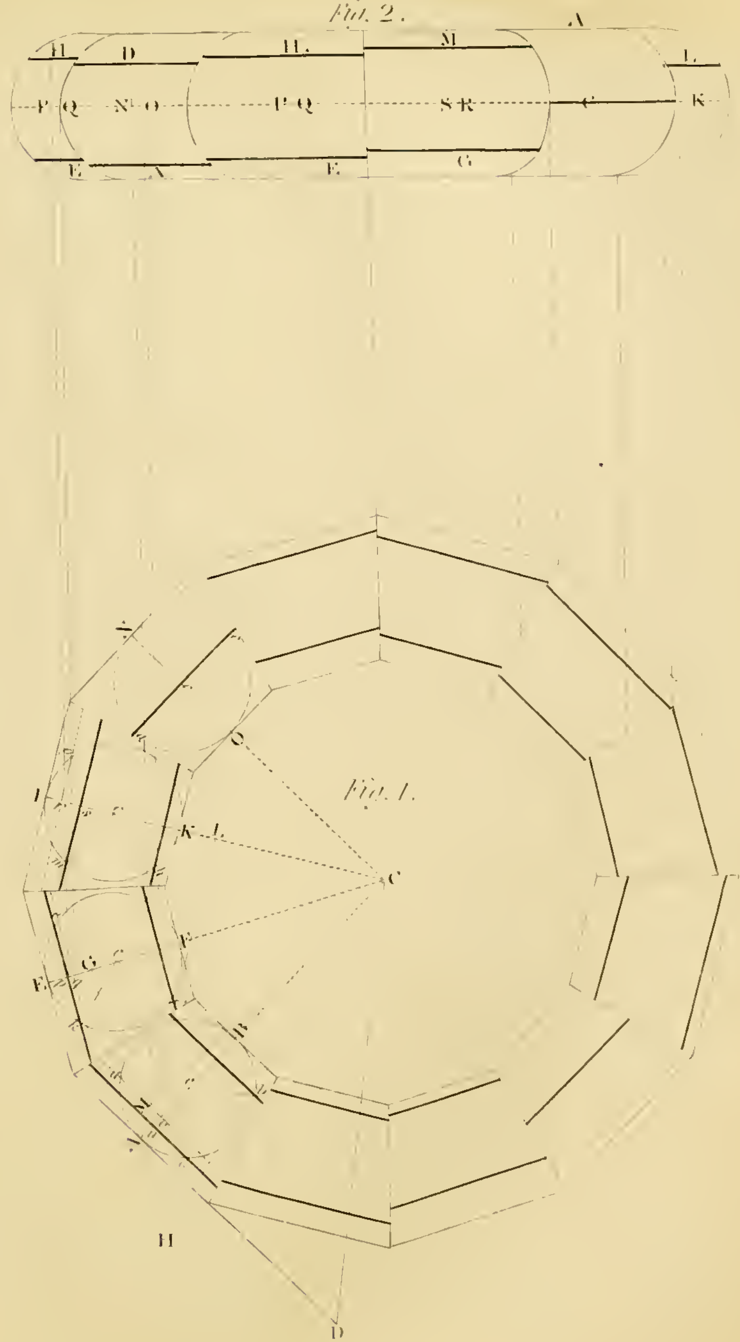


Fig. 2.
Fig. 1.

passing through the axis, and let the angles M L F, Fig. 3, and L F M, Fig. 4, be the angles which a ray of light makes with the base of the cone, and let F N L be a section of the cone passing through the axis, and through F L; consequently, the rays M L and F M will be in that plane.

Produce the rays M L and F M, if necessary, until they cut the sides of the section N F and N L; Fig. 3 will be cut at the points M and L, and Fig. 4 at the points F and M: bisect each of the lines M L and F M; and through N, the vertex of the cone, and the point of bisection, draw N K; through K draw I K G, at right angles to F L; through the points G and F draw the lines G C and F B perpendicular to A D, the representation of the base, cutting A D at B, and C in the elevation, and join B E and C E; then will B E be the lightest line that can be drawn on the surface of the cone, and C E will be the representation of a line which will divide the light side of the cone from the dark side, and B E C will be the representation of half the enlightened side of the cone.

Plate 19.

PROBLEM V.

Given the ichnography and elevation of a polygonal ring, or a ring made of cylinders of equal lengths, and making equal angles with each other, to determine the representation of the boundaries of light and shade on the ichnography and elevation; the sun's altitude and seat to the plane on which the ichnography is described being given.

Let A C be the seat of the sun in the plane of the ichnography, cutting the thickness of the ring at A and B; let A C D be the angle which the sun's rays make with the plane of the ichnography, or seat A C.

Bisect A B in *c;* with the radius *c* A or *c* B describe a circle; and through the centre *c* draw *c d* parallel to C D, cutting the circle at *d;* also through *c* draw the line *a b* at right angle to *c d*, cutting the circles at *a* and *b;* through the points *d* and *b* draw lines parallel tc the sides A and B of the ring; then the dark line nearest to A will represent the line of light; and that which is nearest to B will represent that line which separates the light side from the dark side.

To find the lines of light and shade on the next side of the ichnography: from the centre C draw C E at right angles to the side E, cutting the sides E and F at E and F; through the point A draw H A G at right angles to E C, cutting E C at G; from G make G H equal to A D, join H C, and bisect E F at *c;* then with the radius *c* E on *c* F describe a circle, and through its centre *c*, draw *c k* parallel to C H, cutting the circle at *k;* also through *c* draw *p f* at right angles to *c k;* through the points *k* and *f*, draw lines parallel to the sides E and F; then will the line next to E, that cuts C F at *p*, be the line of light, and the line next to F the line of shade.

In like manner proceed with the side I and K; that is, through C draw the line C I at right angles to the side I, cutting the sides I and K at I and K; bisect I K at *c;* with the radius *c* I or *c* K describe a circle; through the point A, as before, draw the line A L perpendicular to C I, cutting C I at L; from L, make L M equal to A D; join M C; through *c* draw *c m* parallel to C M, cutting the circle at *m;* also through *c* draw *g h* perpendicular to *c m*, cutting the circle at *g* and *h;* then through the points *m* and *h* draw lines parallel to the sides I and K; then the line next to I, which cuts I K at *s*, will give the line of light, and the line next to K the line of shade.

In like manner, to find the common boundary of light and shade upon that side of the ring next to the ichnography, draw lines through the points *a*, *p*, *g*, parallel to the sides A, E, I, as are shown by the dotted lines, which will give lines of shade on the under side of each cylindrical part. The lines for one quarter of the ring being found, the other quarter, on the other side of the seat A C, may be found from the last quarter, each being in the same order, receding from the line A C, or drawing towards it. One half being now found, the other half will be found by observing that opposite sides of the ring are parallel to each other; and, consequently, if one is found, the other will also be found; for the light will be at the same distance upon the same sides of that which is to be found as that cylinder which is found. Then to find the lightest lines on the elevation, Fig. 2, and also those lines which will be the boundaries of the light and shade, proceed as follows:—

Through the points *n*, *o*, *p*, *q*, draw the lines *n* N, *o* O, *p* P, *q* Q, perpendicular to the elevation, cutting the line P K, which represents a plane passing

through the axes of all the straight cylinders at the points P, Q, N, O; make P H equal to *p k;* from Q, make Q E equal to *q c;* from N, make N D equal to *n d;* from O, make O A equal to *o a;* then through the points H, D, E, A, Fig. 2, draw lines parallel to P K; then will the lines H and D represent the lines of light, and E and A will represent the lines of shade. Now, since the side D A, in the elevation, Fig. 2, represents the cylindrical part A B on the ichnography, and because that the lines of light and shade are in the same order on each side of A B, — that is, the light and shade will be the same height from the plane of ichnography, on each of the cylindrical parts that are equidistant from the cylindrical part A B, on each side of it, and, consequently, will be represented on each of the cylindrical parts, Fig. 2, equidistant from A D, at the same altitude, — then make P H and Q E, the next cylindrical part to the centre of the elevation, equal to P H and Q E, on the outside cylindrical part, which the side E F, on the ichnography, represents; make S M and R G, in the elevation, equal to *s m* and *r g* on the ichnography; the height of the lines on each side of the elevation representing the light and shade being taken from its corresponding place on the ichnography, as is already shown, will complete the lines of light and shade on the elevation.

OBSERVATIONS.

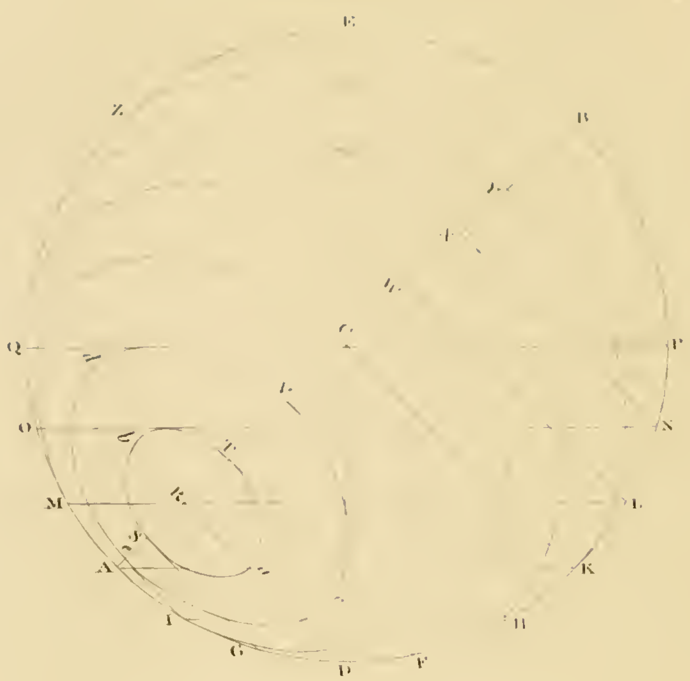
1. If the seat of the sun's rays be drawn on any plane, and if a cylinder lay on that plane with its axis perpendicular to its seat, and parallel to the plane, the lightest line on the cylinder will be nearer the plane in this position than in any other. 2. But if the axis of the cylinder make oblique angles, then the line of light will be higher on the cylinder. 3. Again: if the axis of the cylinder be parallel to the seat of the sun, the lightest line on the cylinder in this case will be at its greatest distance from the plane, because then the line of light will be where a plane passing through the axis of the cylinder cuts the upper surface perpendicular to the plane on which the cylinder lies; the line of light in the first position of the cylinder is brighter than the line of light in the second position, and the line of light in the second position of the cylinder is brighter than the line of light in the third position; the axis of the cylinder in all these cases being parallel and equidistant from the plane of the ichnography; consequently, the lines of light in the first and third positions of the cylinder are the extremes of all the varieties which happen between these two positions; that is, the first is the lightest possible, and the third is the darkest possible. The boundaries of light and shade, called in this book the lines of shade, or those lines which separate the light side from the dark side, are always at a quadrant's distance from each other; and, consequently, that arc which is the under line of darkness in the first position will be higher in the second position, and still higher in the third; and if a plane be made to touch the cylinder upon that line, it will be perpendicular to the plane on which the cylinder lies, and, therefore, its ichnography will be represented by the edge of the cylinder. Now, suppose that cylinder to be turned round by moving continually the same way, until the axis of the cylinder comes into that position in which the axis would be perpendicular with its seat, then the line of darkness would be in its highest position.

Plate 19.

PROBLEM VI.

To find the lightest line, also the line that divides the lightest side from the dark side on the ichnography and elevation of a circular ring.

Let A C be the seat of the sun, or any line parallel to it, passing through the centre C of the ichnography, (Fig. 1,) cutting the thickness of the ring at B and H, and let B C D be the sun's altitude; take the point G, at one quarter of the circumference of the ring, distant from the point B; and take any points E and F in the circumference between B and G, and draw the lines E C, F C, and G C, cutting the inside of the ring at I, K, and L; through the point B draw the lines B M, B N, and B U, each respectively perpendicular to E C, F C, and G C, cutting E C, F C, and G C, at O and P; make O M, P N, and C U, on B H, E I, F K, and G L, as diameters; describe circles whose centres are *a, b, c, a;* through these centres draw the lines *c, d, c, m, c, n,* and *w, u,* parallel to C D, C M, C N, and C U, cutting the circles at *a, m, n, u,* and *c, c, c, w;* also, through the centres *a, b, c, v,* draw lines *i, q, p, s, k, y,* and L G, respectively perpendicular to C D, C M,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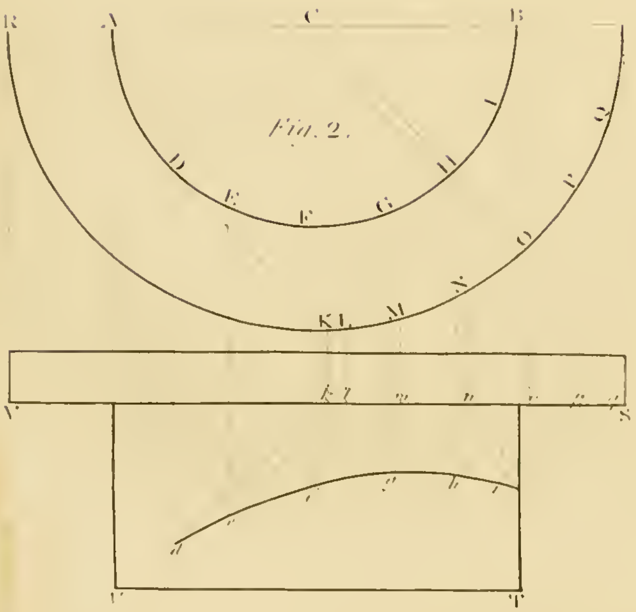
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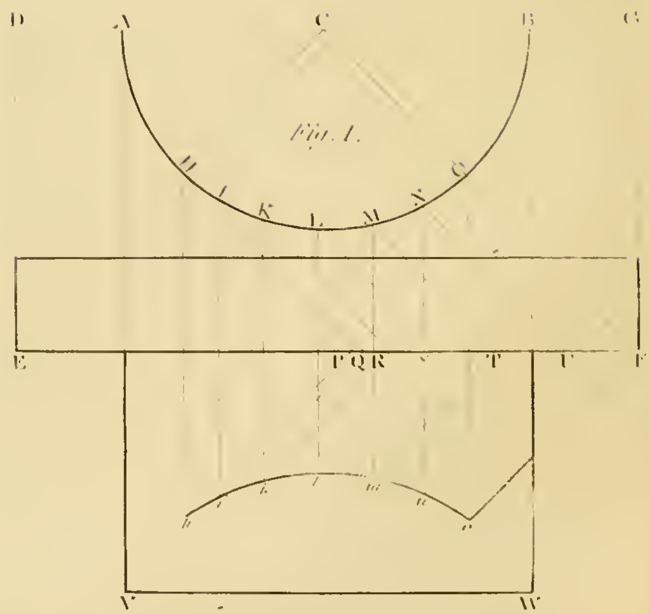
Fig. 2.


D
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P Q R
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W

Fig. 1.

C N, and C U, cutting the circle at i, q, p, s, k, y, L and G.

Through the points d, m, n, u, draw the lines d, g, m, e, n, o, and u, v, perpendicular to the diameters B H, E I, F K, and G L, cutting B H, E I, F K, and G L, respectively at the points g, e, o, v; draw a curve which will be part of the line of light for one quarter; also through the points q, s, y, draw the lines q, r, s, t, and $y\ x$, cutting the diameters at r, t, x; then through the points r, t, x, and L, draw a curve line $r\ t\ x$ L, which will be the upper line of shade for that quarter, or that line which divides the dark side from the light side, upon the upper side of the ring on that half which is next to the luminary.

One quarter being now found of the line of light and shade on the ichnography of the visible side of the ring, the other three quarters will be found from that quarter which is already found, in the same manner as in the last problem, and the points D, M, N, U, I, P, K, G, also in the elevation of the curves D, M, N, U, and I, P, K, G, being drawn, then D M N U will be the line of light, and I P K G the line of shade.

Plate 20.

PROBLEM VII.

To represent the lines of equal gradation on the surface of a sphere given; the seat of a ray of light on the plane of projection, and the elevation of the ray.

Let A B be the diameter of the sphere and seat of the sun. Find the centre C, and describe a circle with the radius C A or C B; this circle will represent the contour of the sphere. Make the angle A C D equal to the elevation of the ray above the seat C A; and let C D be produced so as to cut the circumference line in D and E. Draw the lines F G, H I, K A, L M, N O, P Q, perpendicular to D E, to cut the circle at the points F, G, H, I, K, A, L, M, N, O, P, Q; then will F G, H I, K A, L M, N O, P Q be the diameters of circles which have equal intensities of light around each circumference on the sphere. Draw D R, G S, F T, H V, K C, L W, N X, P Y perpendicular to B A; then R will be the projected point, representing the lightest point on the surface; T S is the shorter axis of the ellipsis, and F G the greater. Describe the ellipsis a T b s, which will represent a circle of equal intensity of light in every part of its circumference on the surface of the sphere. In like manner, if the ellipsis c V d e be drawn, it will represent another circle of equal intensity. Proceed in this manner, and represent all the intermediate circles of the sphere to that, the diameter of which is P Q, where a ray of the sun would at any point be a tangent, and the representation of this last circle, K Y Z, will be the line of separation of light and shade; then every succeeding ellipsis towards the lightest point R will represent graduating lines continually lighter.

PROBLEM VIII.

Given the ichnography and elevation of a cylinder, having a square projecture or abacus, and the seat of the sun on the ichnography, also its seat on the elevation; to find the shadow of the abacus, also the line of light and shade on the cylinder.

Let A H I K L M N O B be the ichnography of the cylinder; D E F G that of the abacus; V W the elevation of the cylinder; and E F the elevation of the abacus; let C F be the seat of one of the sun's rays on the ichnography, passing through the centre C; draw F o, making an angle with E F, equal to the angle which the seat of any of the rays make with E F; through C draw C H perpendicular to C O, cutting the ichnography at H; between the points H and O, take any points I, K, L, M, and N; then through the points H, I, K, L, M, N, draw lines B B, I Q, K R, L S, M T, N U, parallel to C F, cutting H P at P, Q, R, S, T, U; through the points P, Q, R, S, T, U, draw lines parallel to F o; also through the points B, I, K, L, M, N, O, draw lines H h, I i, K k, L l, M m, N n, O o, parallel to the sides of the cylinder, cutting P h, Q i, R k, S l, T m, U n, F o, at the points h, i, k, l, m, n, o; through these points draw a curve, and it will be the shadow of the abacus; H h will be the line of shade, and O o the line of light.

PROBLEM IX.

Given the ichnography and elevation of a cylinder having a circular projection over it; the seat of the sun on the ichnography; also its seat on the elevation being given; to find the shadow of the projecture on the cylinder: also the line of light and shade.

Fig. 2. Let A D E F G H I B be the ichnography

of the cylinder, R K L M N O P Q the ichnography of the projection; let U T be the elevation of the cylinder, and V S that of the projecture; also, let C O be the seat of the sun's rays, passing through the centre C of the ichnography, and *o h* the seat of the sun on the elevation.

Through C draw C D perpendicular, cutting the circumference of the inner circle at D; take any point E, F, G, I, B, in the circumference; draw the lines B K, E L, F M, G N, H O, I P, and B O, parallel to C H, cutting the outward circle at the points K, L, M, N, O, P, Q; from the points D, E, F, G, H, I, draw the lines D *d*, E *e*, F *f*, G *g*, H *h*, I *i*; also, through the points K, L, M, N, O, P, Q, draw the lines K *k*, L *l*, M *m*, N *n*, O *o*, P *p*, Q *q*, cutting V S at the points *k*, *l*, *m*, *n*, *o*, *p*, *q*; through the points *k*, *l*, *m*, *n*, *o*, *p*, *q*, draw *k d*, *l e*, *m f*, *n g*, *o h*, *p i*, parallel to *o h*, cutting the lines D *d*, E *e*, F *f*, G *g*, H *h*, I *i*, at the points *d*, *e*, *f*, *g*, *h*, *i*; a curve being traced through these points will be the representation of the shadow upon the cylinder; D *d* will be the line of shade, and H the line of light.

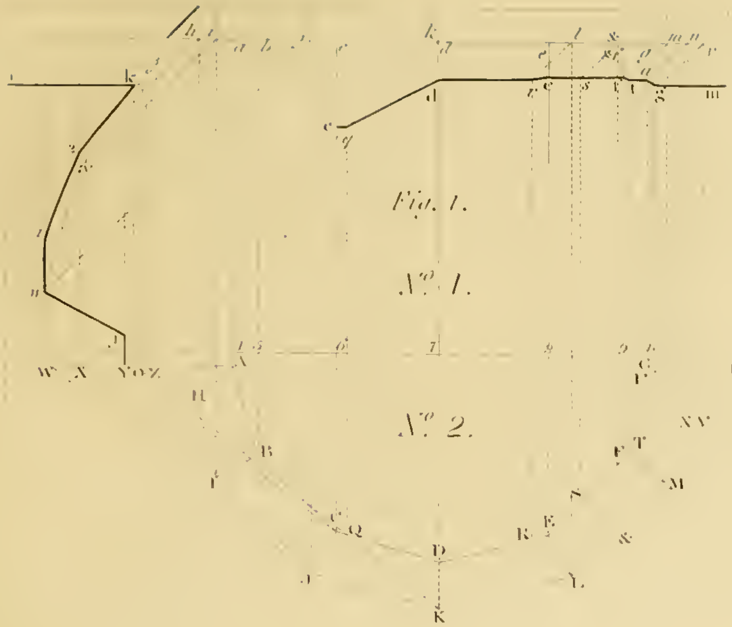
Plate 21.

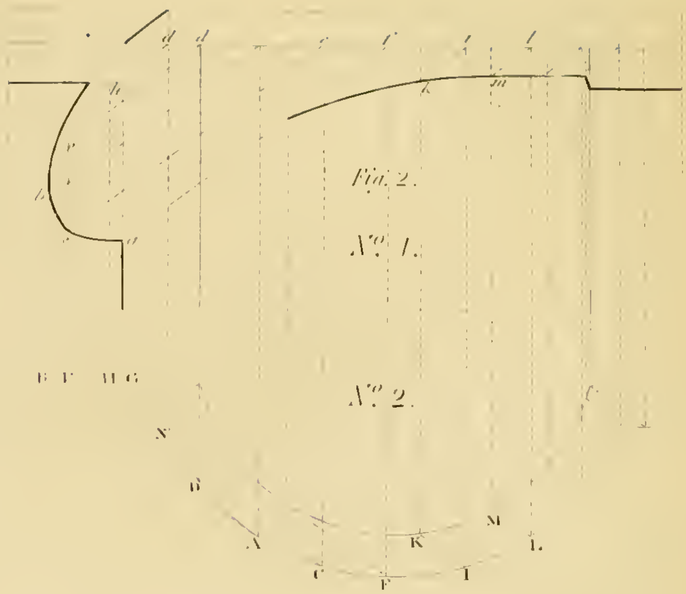
PROBLEM X.

The ichnography and elevation of the prism standing upon a polygonal base, having the projecture or cap of the same figure upon it, projecting equally over its sides; given the seat of the sun's rays on the plane of the ichnography, and also on the elevation; to project the shadow of the cap on the prism, and also on a plain parallel to the axis of the prism.

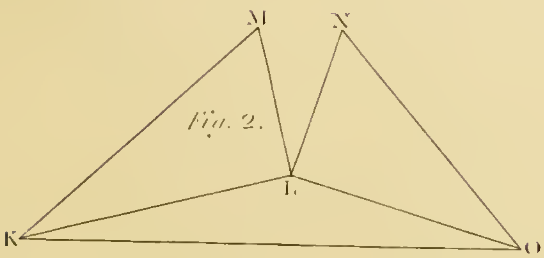
Let A B C D E F G be the ichnography of the prism, H I J K L M N the ichnography of the cap W A and G P, parts of the ichnography of the plane on each side of the prism, J W be the projection of a ray on the ichnography, and *j w* on the elevation. From all the points H, I, J, K, L, M, N, in the ichnography of the angles of the cap, draw the lines H *h*, I *i*, J *j*, K *k*, L *l*, M *m*, N *n*, perpendicular to W P, to cut the under side of the cap at *h*, *i*, *j*, *k*, *l*, *m*, *n*. Draw the lines A 4 *a*, B 5 *b*, C 6 *c*, D 7 *d*, E 8 *e*, F 9 *f*, G 10 *g*, perpendicular to W P, cutting the bottom of the prism at 4, 5, 6, 7, 8, 9, 10, then the lines 4 *a*, 5 *b*, 6 *c*, 7 *d*, 8 *e*, 9 *f*, 10 *g*, represent the angles on the elevation. Draw the lines H Z, I X, J W, K Q, L R, M T, N U, parallel to J W, cutting the ichnography of the plane at the points Z X W, and the ichnography of the prism at Q, R, T, U. Through the points *h*, *i*, *j*, *k*, *l*, *m*, *n*, the projection of the angles of the cap on its under edges, and parallel to *j w*, draw the projections of the rays *h z*, *i x*, *j w*, *k q*, *l r*, *m t*, *n u*. Draw the perpendiculars Z *z*, X *x*, W *w*, Q *q*, R *r*, T *t*, U *u*, then the points *z*, *x*, *w*, are the projections of the angles of the cap on the plane, and *q*, *r*, *t*, *u*, the projection of the other angles on the elevation of the prism. Draw C Y, to touch the prism at C, and draw Y *y* perpendicular to W P, then Y *y* will be the termination of the shadow of the body of the prism on the wall. Then, because that the point *q* is in the plane 6 *e d* 7, the point *r* in the plane 7 *d e* 8, and the points *t* and *u*, in the plane 9 *f g* 10, and the lines *j*, *k*, *l*, *m*, *n*, parallel to these planes, the lines *j*, *k*, *l*, *m*, *n*, will make parallel shadows; therefore, draw *q c*, *r d*, *t u*, parallel to *j*, *k*, *l*, or *m n*, to cut *c* 6 in *e*, *k* 7 in d, and G *g* at *n*; join d *q*; then, to find the depth of the shadow of *l m* on the elevation, draw *ꝭ s* on the ichnography parallel to J W; draw *ꝭ* & perpendicular to W P, likewise *ꝭ* s, parallel to the ray on the elevation, and S *s* parallel to the axis of the prism; then *s* is the depth of the shadow; but as the projections of the extremities of *l m* fall upon the adjacent planes at *r* and *t*, draw e f through *s*, cutting 8 *e* at e, and 9 *f* at f; then join e *r*, f *t*. Lastly: draw G V on the ichnography parallel to W J, cutting the projection of the cap at V; draw V *v* perpendicular, cutting the cap at *v*, and draw *v* g parallel to the rays on the elevation, and join *u* g; then e *q* d, *r* e f *t u* g will be the shadow of the cap on the elevation; but as the shadow of the parts of the abacus H I, I J, will be from the top of the cap, make *w* 1, *x* 2, *z* 3, parallel to the angles of the prism on the elevation, and equal to the thickness of the cap. Join 1, 2; 2; 2, 3; then will 3, 2, 1 *w y* be the shadow of the abacus on the wall. Through g draw g m and k i in the same straight line with g m, cutting 3 2 at k; then i k 2, *l w y*, is the complete shadow of the cap on the plane.

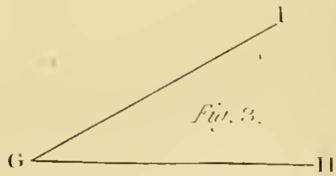
Much after the same manner may the shadow of a cylinder be found, having a circular projection over it, as is shown at Fig. 2, and also the shadow of the cylinder projecture may be found on a plane parallel to the axis of the cylinder, having the same thing given as before; but for more easy inspection, letters





The intersection of a Plane perpendicular to the horizon.





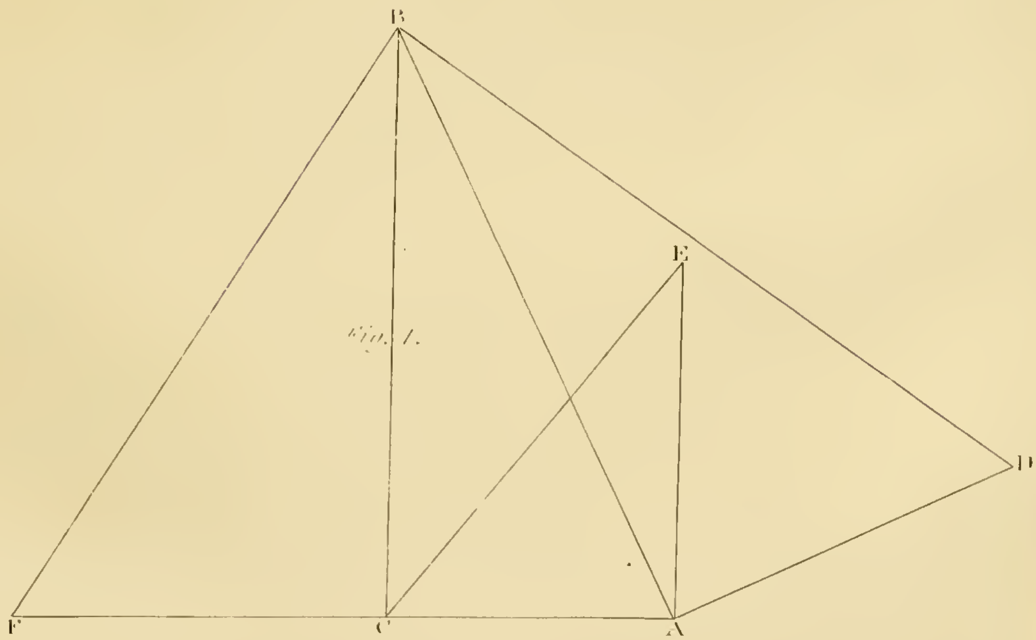
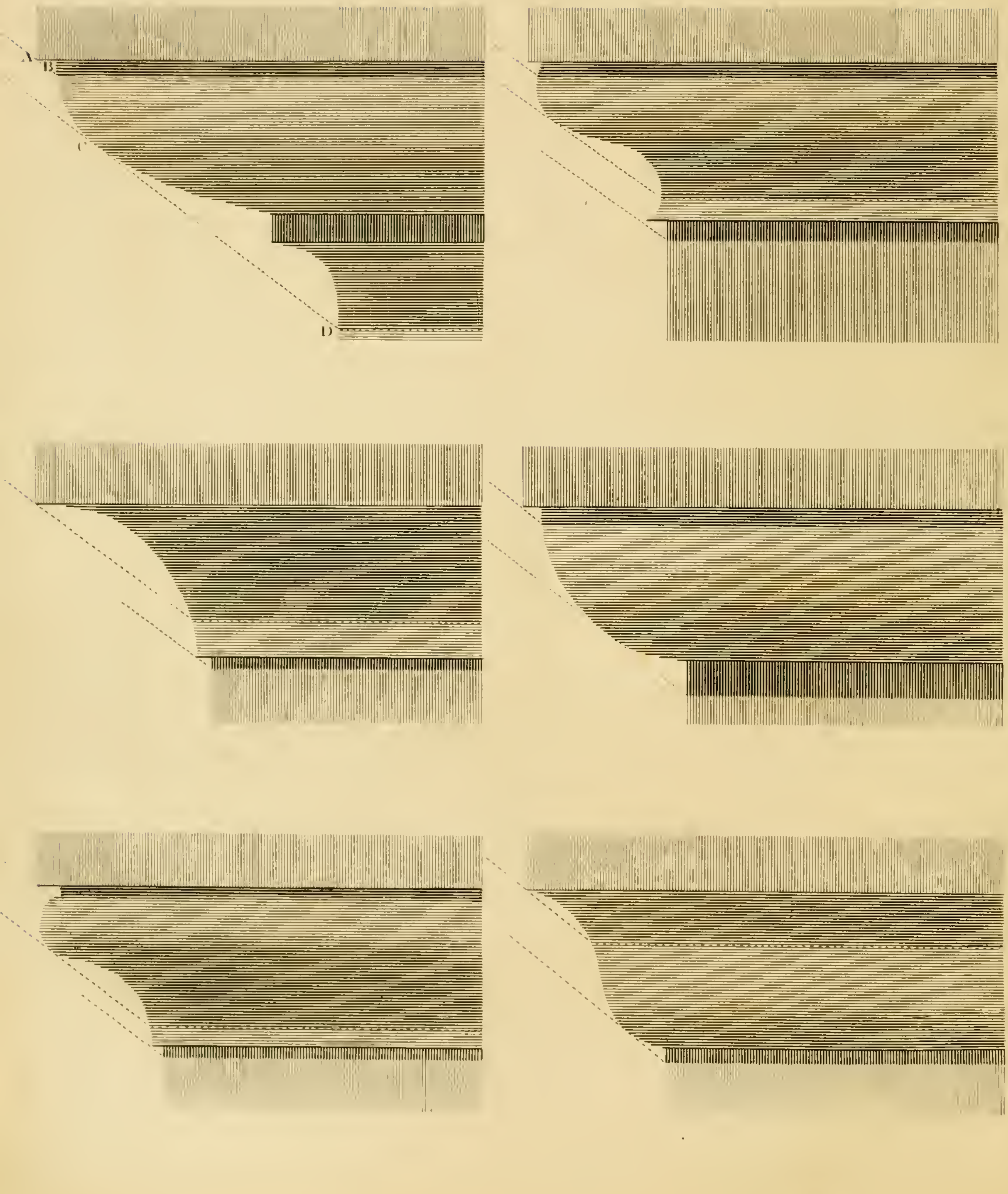


Fig 1



are placed on the ichnography and elevation, representing the corresponding parts of each other; that is, capital letters are placed on the ichnography, and small letters of the same name on the elevation, representing those of the same name on the ichnography.

PROBLEM XI.

Given the seat and altitude of the sun on any plane, also the seat and altitude of a line to the same plane; to determine the shadow of the line upon that plane.

Let K L be the seat of the line upon the plane, and G H, Fig. 3, the angle which the line makes with its seat; make the angle M K L, Fig. 2, equal to the angle H G I; through L draw L M, perpendicular to K L, cutting K M at M; also, through L draw L O parallel to the seat of the sun. Again: through L draw L N perpendicular to L O, and make L N equal to L M; then upon the right line L N, and from the point N, make the angle L N O equal to the complement of the angle of the sun's inclination to a right angle; produce N O, cutting L O at O; then join the points K and O, and the line K O will be the shadow required.

This problem will be found of great use in finding the shadows upon inclined planes.

NOTE. If the seat and altitude of the sun be given on any other plane, making a given angle with the plane on which the shadow is to be projected, the sun's altitude and seat may be found by Problem II.

PROBLEM XII.

Given the seat and angle of inclination of the sun on the horizon, and the intersection of a plane perpendicular to the horizon; to determine the angles which a plane of shade, made by a right line, parallel both to the horizontal and perpendicular planes, will make with each of the planes.

Let A B be the seat of the sun on the horizon, and A A D, as Fig. 1, the angle of inclination to the seat A B, and let C B be the intersection of a plane perpendicular to the horizon; take any point C in C B, and from C draw C A perpendicular to C B, cutting A B at A; from A, draw A E perpendicular to A C, and A D perpendicular to A B, cutting D B at D; make A E equal to A D, and join C E; then will the angle B C E be the angle which the plane of shade makes with the perpendicular plane, and the angle A C E the angle which the plane of shade makes with the horizon.

This problem will be very useful in shading mouldings which project from planes that stand perpendicular to the horizon, the sun's altitude and seat being given to the horizon, as will be shown in the next problem.

Plate 22.

PROBLEM XIII.

A moulding of any kind being given, and the angle which a plane of shade makes with a perpendicular part of the moulding, either being given or found by the last problem, having the sun's altitude and seat on the horizon; to determine the shadow on the moulding.

Let the ovolo, fillets, and hollow, Fig. 1, be the given moulding; draw C D parallel to the inclination which the plane of shade makes with the vertical part of the moulding, touching the ovolo at C, and cutting the vertical part below D; then a line drawn through D perpendicular to the fillet will give the lower edge of the shadow, and an imaginary line, supposed to be drawn through C, will give the line of shade; and if a line is drawn through A, the lower edge of the fillet above the ovolo parallel to C D, cutting the ovolo at C, then a line being drawn through B, parallel to the fillet, will give the edge of the shadow from the fillet.

Much in the same manner, may the shadow upon the *cima reversa* and *cima recta* be found, as shown by the dotted lines.

ON MOULDINGS

Plate 22.

The form or shape of mouldings, in most cases, may be ascertained from the various degrees of light and shade upon them, without ob-

serving the profiles; which will appear evident from the following observations: —

Observations on Surfaces, and their Power to reflect Light.

It has already been observed in the second proposition, that if the sun's rays fall upon a reflecting plane, the angles made by the reflected rays, with perpendiculars at the impinging points, will be equal to the angles made by their corresponding incident rays with the said perpendiculars; so that the rays in this case will have only one direction after reflection: but by experiment we are shown that there is no such thing as a perfect plane; for, if a surface is even polished to the greatest degree, yet this polished surface will be but rough and uneven; for, if viewed through a microscope having a great magnifying power, the surface will appear quite irregular, and the different parts of the surface will be inclined to any fixed plane, in all manner of directions; and, consequently, if the sun's rays fall upon such a surface, the rays will not be entirely reflected in the same direction, but a great part of them will be reflected in all manner of directions by the different positions of the surface, by Proposition IV. It may be observed, that the higher any surface can be polished, the nearer it approximates to a plain, and, consequently, the rays will be more and more reflected in the same direction; but there is no surface which will reflect the sun's rays entirely in the same direction; that is, parallel to each other; but a great part of them will be reflected in all manner of directions: it will be also necessary to observe, that the power of reflection will depend very much on the lightness of the color of materials; for the darker any substance is, the more will the rays of light be absorbed in that substance, and, consequently, will have a less power to reflect.

White, being the lightest of all colors, will reflect the most rays; and the more any substance inclines to a white, the greater power will that surface have to reflect the rays of light.

CASE I.

Observations on Mouldings in Shade.

If the sun's rays fall upon any building, also upon the ground or horizon below the building, and if there are any projectures from the building, such as mouldings or other ornaments, and if any of the parts of those mouldings or ornaments are entirely in shadow by the projecture of something else which prevents the rays of the sun from falling upon them, those parts of the mouldings which are in shade will become visible; for, besides a reflection from the ground, there will be a strong reflection from the surface of the building, immediately under the mouldings or ornaments. It has already been observed, that these rays will be reflected in all directions, and, consequently, a part of them will be reflected upwards on the mouldings above, and, therefore, will show light and shade on the mouldings according as the reflected rays fall, more or less, perpendicular on their surfaces.

Hence the reason why all perpendicular sides of fillets will be darker in shade than the horizontal sides.

An *ovolo*, having a projecture over it, so as to prevent the sun's rays from falling upon it, the reflected rays being more and more inclined from the under edge towards the upper edge, will be lightest below, and will be gradually darker and darker upwards.

A *cavetto* or *hollow*, immersed in shade, will, for the same reason, be darkest below, and will be continually lighter to the upper edge.

A *cima reversa*, in shade, will be darkest above and below, and lightest in the middle; for this moulding is composed of an ovolo above and a cavetto below.

A *cima recta*, in shade, will be lightest above and below, and darkest in the middle.

These are general rules for shading horizontal mouldings.

CASE II.

Observations on vertical Mouldings.

All upright perpendicular mouldings, in shade, or being in part so, will receive a reflection from those surfaces which are next to them; for they cannot receive a reflection from the contrary side, by reason of their projection, which will prevent the ray, reflected from that side, from falling on them.

Therefore, it is plain, in these cases, the forms of mouldings may be known by reflection.

Artists give this rule for shadowing: that is, to shade all mouldings or other ornaments which are in shade, inverse to those on which the sun's rays fall, from the contrary side of the reflected rays. But this rule is not only very uncertain, depending much on the situation of other objects which surround these

mouldings or ornaments, but in some cases very erroneous, as in the example of mouldings perpendicular to the horizon; for mouldings in this situation, as has been observed, will receive a reflection from that side which is next to the front of the moulding, if something else does not project to a great distance from that surface from which the reflection comes. If a cylinder or column is attached to a wall in a vertical position, and if it has any projecture over it, so as to cause that part under the projecture to be in shade quite round the cylinder, there will not only be a reflection from the wall on the contrary side of the cylinder, to the sun upon that side of the cylinder which is next to it, but also from that part of the wall on that side of the cylinder next to the sun, which will make that part of the cylinder which is in shadow lightest at the two sides and darkest in the middle. Something of the same kind may be seen in Ionic columns attached to a wall, where it may be observed when the sun shines upon one side of them; suppose that side of the column which is on the right hand, then the right hand volute will throw a shadow upon the light side of the column, which shade will be lightest on that edge which is next to the wall and to the luminary, and darkest at that edge next to the middle of the column.

CASE III.

Observations on Mouldings in Shade, when situate on the Side of an Object which is entirely in Shade, and also the Ground under that Side in Shade.

In one building where one end or side is entirely in shade, and also a great part of the ground under that end in shade, there will be little or no reflection from the ground upwards, nor from the surface of the building, and, consequently, little reflection upon the mouldings from below; the only light which they receive is from a kind of scattered or confused rays in the atmosphere, and small reflections from the horizon; and, therefore, horizontal mouldings, or ornaments, in this situation, which have but small projectures over them, will have a contrary effect to mouldings in shadow situate on the light side of an object.

An *ovolo*, placed horizontally, and whose greatest projecture is upwards, upon the dark side of an object, will be lightest above, and continually darker and darker to the under edge.

A *cavetto*, having its greatest projecture upwards, placed horizontally on the dark side of an object, will be darkest above, and continually lighter and lighter to the under edge.

A *cima reversa*, placed horizontally on the dark side of the object, having its greatest projection upwards, will be darkest in the middle, and lightest above and below.

A *cima recta*, whose greatest projecture is upwards, and placed horizontally, will be darkest above and below, and lightest in the middle.

All horizontal projectures on the dark side of an object will condense the shade under them, and, consequently, will appear more or less dark according as the projecture is more or less.

These are general rules for shading mouldings on the dark side of an object from scattered light; however, there are some exceptions to these rules — that is, when any of these mouldings have a very great projecture over them, this projecture will hinder the scattered rays from falling upon the mouldings; but as they will receive a small reflection from the horizon below, the most of the scattered and reflected rays will fall obliquely on the moulding; thus the lighted place of an ovolo will not be exactly on the under edge, but somewhere between the under and upper edge, and will be nearest to either, according as the shadow on the ground is less or more distant from that side of the object, and according as the projecture over the moulding is more or less, and also according to the position and distance of other surrounding objects; all these different circumstances combining together will vary the places of light and shade on horizontal mouldings, which are situate on the dark side of an object.

An horizontal cavetto on the dark side of an object having a projecture over it as before, the lightest place will be somewhere between the upper and under edge, as in the ovolo, and both mouldings would have actually the same appearance if their profiles could not be observed, when most of the scattered and reflected rays are in a plane, making equal angles with the horizon, and with that side of the object in shade — that is, forty-five degrees with each other; and, consequently, mouldings in this situation will be less distinct than mouldings in shade on that side of the object which the sun shines on.

Further Observations on the Effect that reflected Light will have on Cornices which have Modillions or Mutules, Dentils, &c., or any other projecting Ornaments of a Nature similar to them.

The reflected light from the ground and from the object being scattered in all directions, it will therefore follow, if there are any projecting parts from mouldings or cornices, which are in shadows, such as mutules, modillions, dentils, &c., these projecting parts will hinder a great part of the scattered rays from falling in the spaces between them; and therefore the spaces will be deprived of reflection, and, consequently, will be much darker than the prominent parts, even if these prominent parts were also in shadow.

For this reason, the intervals between mutules, modillions, dentils, &c., are darker than on their fronts, for every projecture will condense the shadow on each side of it, if recessed on both sides; therefore, the spaces will be lightest in the middle, and darkest nearest to the edges of the mutules, modillions, dentils, &c.; but to show on which side of the mutules, &c., the greatest shade would fall, according to the place of the luminary, would be almost impossible, as it depends so much on the situation of other objects. But suppose all the surrounding objects in the vicinity to be removed, and the ground and building to be of a light color, and suppose the rays to proceed from the right to the left hand of the object, and parallel to a vertical plane which is inclined at an angle of forty-five degrees with the elevation of the object; then it is plain that, since the angle of reflection is equal to the angle of incidence, the greatest part of the rays which fall upon the horizon will be reflected from the ground parallel to the vertical plane; and seeing that the vertical plane would be on the right hand of another vertical plane, perpendicular to the face of the object and to the horizon, it follows that most of the rays will come from the right hand, and be reflected towards the left on the object; and, consequently, any projectures from cornices, as mutules, &c., which are in shadow, will condense or darken the shade upon the left hand of the projecture, and that vertical side of the mutules which is next to the luminary will be lighter than the other vertical side on the left of the mutule, &c. As to the direction and effect which most of the reflected rays would take from the face of the object, imagine a plane parallel to the sun's rays, and perpendicular to the face of the building or object; then most of the rays will be reflected from the building or object downwards, parallel to this last-mentioned plane; and that part of those rays which are reflected upwards would take no particular direction to the right or to the left, and, therefore, would cause no sensible difference upon the vertical sides of the mutules, but would reflect most light upon the horizontal or under sides, &c.

What has now been said of mouldings in shade having projectures from them, or of the recessed parts of any object, will apply to ornaments in shade which are deeply relieved; for their recessed parts, according to the foregoing observations, will be deprived of reflection by the more prominent parts of them; they will, therefore, be darkest in their receding parts, and lightest on the prominent parts.

Observations on the Shades of Projectures from Buildings, or from any other plain Surface which is made of light Materials.

If there is any vertical plane, and if a rectangular prism is attached to that plane, having two of its sides parallel to the plane, — and, consequently, the other two sides perpendicular to it, — then, if the sunshine on the plane be on either side of the prism, the other opposite side of the prism will cause a shadow to be projected from its edge upon the plane; and if the shadow upon the plane be of no considerable breadth, and if the plane be extended at any considerable distance beyond the shadow, then the lightest part of the plane on which the rays fall will reflect a great part of the rays towards the prism; but as these reflected rays will not fall upon the shadow, it will be deprived of reflection; but as the side of the prism which projects the shadow is opposed to the reflected rays, that side of the prism will receive a strong reflection, which will cause it to appear much lighter than the shadow it throws on the plane; but if the shadow be projected farther on the plane, it will diminish the reflecting surface behind the prism, and will also cause the reflecting surface to be at a greater distance from the side of the prism, and, consequently, will receive less reflection from the plane; and, in general, the reflection on the prism will be continually diminished, according as the shadow on the plane is increased, till at last there will be no difference between the shadow on the plane and the side of the

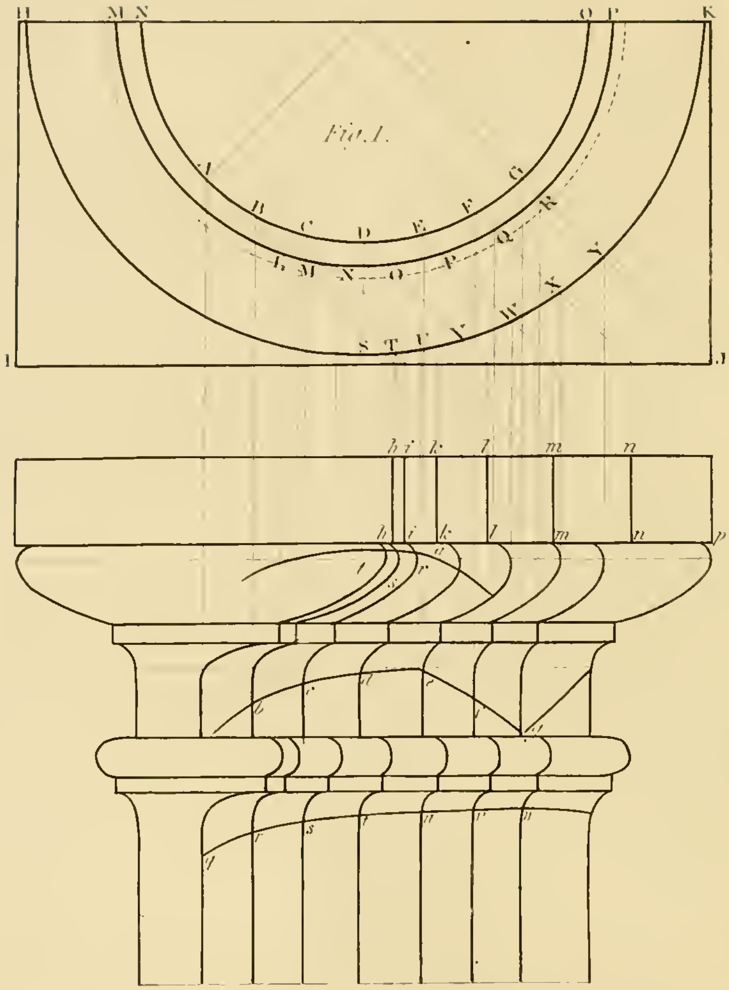


Fig. 1.

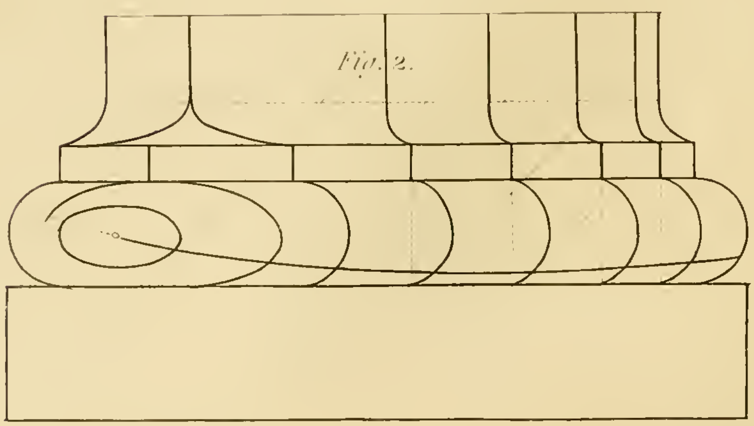


Fig. 2.

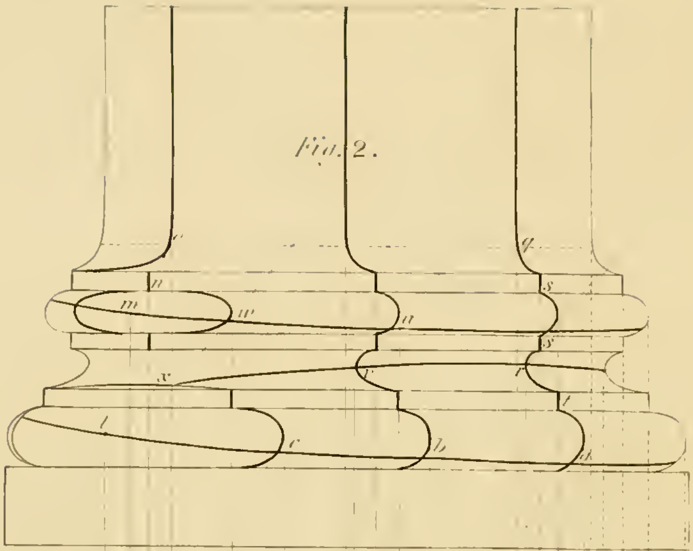


Fig. 2.

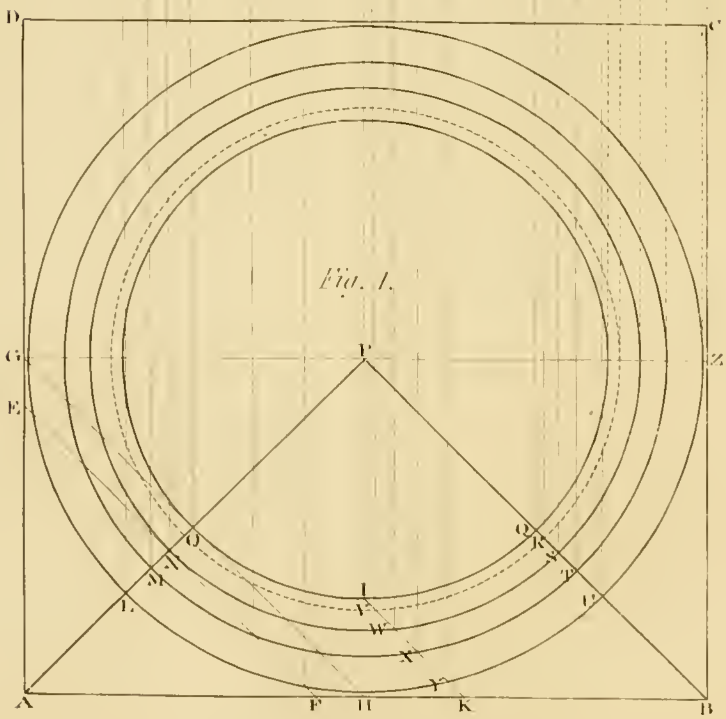


Fig. 1.

prism which projects that shadow; and if the plane be entirely deprived of light, by the extensive breadth of the shadow, the side of the prism will in general be darker than the shadow on the plane: but this will depend very much on the situation of other objects.

A building consisting of light-colored materials, having a break in the front which projects a shadow on the building, at a small distance from the break, will, for the reason before mentioned, be much lighter on the side of the break than the shadow projected by it on the building behind it; also, columns which are attached to a wall will project a darker shadow on the wall than any part of the columns which throw the shadow, provided that the shadow is not any considerable distance from the column; for, according to the above observations, the broader the shadow, the less the column will appear to be relieved from it.

Observations on the light Side of the Prism, and the Effect that a Reflection from the Horizon and from the Object will have on the Plane behind the Prism.

The rays of the sun being reflected from the horizon in all directions, the projecture of the prism will prevent a part of the reflected rays from proceeding to the plane behind the prism, and, consequently, the plane would be something darker than the face of the prism which is parallel to it; but the side of the prism adjoining to the plane will throw a reflection upon the plane, and, therefore, it would be difficult to perceive the difference between the face of the prism and the plane parallel behind the prism. As to the difference of light between the side of the prism, which is perpendicular to the plane, and the plane, it will very much depend on the situation of the luminary; for if the luminary is in a plane equally inclined to both, there will be nearly the same degree of light on each; for very little difference will arise from the reflection, except the luminary is more inclined to one surface than another; and then that surface will be darker than the other, according to the obliquity of the rays of the sun on that surface.

PROBLEM I.

Plate 24.

Given the ichnography and elevation of a base and capital, and the seat of the sun's rays on the ichnography, and on the elevation; to project the shadows caused by the several parts of itself, and the line of shade upon the base.

Imagine the object to be sliced, or cut, by as many planes, parallel to the axes of the columns,* and to the sun's rays, as may be thought convenient for the purpose: then it is plain, if a ray of light enter any of those planes, that every part of the ray will be in that plane, and that the projecting parts upon the edges of these planes will withhold the rays from a part of the edge of the plane; and the lowest point of that part will give the edge or projection of the shadow of the part which throws the shadow: then, if a sufficient number of these points are found, a line drawn through them, with a steady hand, will give the shadow; the line of shade will be found by drawing lines to touch the several sections parallel to the seat of the sun's rays on the elevation; and a line being drawn through the points of contact of the sections, will give the line of shade.

Let H I K be the ichnography of the abacus; H S K the ichnography of the ovolo; and M P L that of the astragal; the lines G Y, F X, E W, D V, C U, B T, and A S are lines drawn parallel to the ichnography, cutting the front I K, of the abacus, and from the seats on the ichnography, and the several seats on the elevation, the shadows may be described, as is shown in the elevation: then lines are drawn to touch the most prominent parts of those sections; and the places where they cut the other parts of the sections will be the projections of the several points as before, and a line being drawn through these points will give the shadow.

The part G F E is the shadow from the abacus, and D C B the shadow from the ovolo; thus the point *g* in the elevation is the shadow of P; *f* is the shadow of N, and E the shadow of *m*; and the shadow of the other part of the abacus would be where the dotted curved line is represented; but as the sun shines on the ovolo, in the middle of the abacus, it will throw the shadow lower than the dotted lines. This will be found by drawing lines to touch the several sections, which will give the points B, C, D.

* It is not absolutely necessary to suppose the plane parallel to the axis of the column, as in this problem; but the sections formed by planes in this position are more easily found than in any other, for which reason I prefer the above position of planes.

Note. — That the line of shade on the torus might have been found in a very different manner than is shown in this example, may be seen by the circular ring, plate 19.

Much after the same manner may the shadow and lines of shade be found on the attic base, as is shown in plate 24.

PROBLEM II.

Plate 25.

Fig. 1. To find the shadow of a cylindrical recess in a wall, whose axis is perpendicular to the plane of the wall; having the seat of the sun's rays on the ichnography and elevation.

Let Fig. 1 be the elevation of the wall, and C D the diameter of the cylindrical recess; and let E F G H be the ichnography; bisect C D at *a;* draw A *a* perpendicular to E H, cutting it at A; through A draw A B parallel to the seat of the sun's rays on the ichnography, cutting F G at B; through B draw B *b* parallel to A *a;* and through *a* draw *a b* parallel to the seat on the elevation, cutting B *b* at *b;* then on B as a centre, with one half of C D, describe a part of a circle, as is shown by the dark line, and it will be the edge of the shadow.

Much in the same manner may the shadow of a recess, which has a back parallel to the plane of the wall, be found, as is shown at Fig. 2.

PROBLEM III.

Fig. 3. To find the shadow of a recess constructed as in Fig. 2, when the sides of the ichnography are inclined to the intersection of the two planes of the ichnography and orthography given, the intersection of a number of planes passing through the luminary perpendicular to the plane of the elevation.

Let Z *b*, W Y, T V, and Q S be the intersection of as many planes passing through the sun perpendicular to the elevation, and let Q R be the projection of one of the sun's rays on that plane; also, let H I be the seat of the sun on the ichnography, cutting the back F G of the elevation at I; from I draw I N perpendicular to I *d*, the common intersection of the ichnography and orthography; from M, draw M N parallel to Q R, cutting I N at N; through N draw N O parallel to M U; on O as a centre, and with the distance O N, describe the arc N R, cutting the side of the recess at R; through the points S, V, Y, *b*, draw S R, V U, Y X, and B *a*, parallel to I *d;* and through the points Q, T, W, Z, draw the lines Q R, T V, W X, and Z *a*, cutting the lines S R, V U, Y X, and B *a*, at the points U, X, *a;* then through the points R, U, X, *a*, draw the curve R U X *a*, and the line I N R U X *a* will be the edge of the shadow required.

PROBLEM IV.

Fig. 4. To find the shadow of a hemisphere niche; given the seat and altitude of the sun's rays on the elevation.

Let I N, G M, E L, and C O be lines parallel to the seat of the sun's rays; and on these lines, as diameters, describe semicircles I K N, G H M, and E F L; draw the line A B, bisecting O C; from any of the points C, E, G, I, as C, make the angle O C D equal to the sun's altitude, cutting the side of the niche at D; through the other points E, G, I, draw E F, G H, and I K, parallel to C D, cutting the semicircles E F G, G H M, and I K N, at the points F H K; through the points D, F, H, K, draw lines D *d*, F *f*, H *h*, and K *k*, perpendicular to the diameters, cutting them at the points *d*, *f*, *h*, *k;* and through the points A *k*, *h*, *f*, *d*, draw a curve, which will be the edge of one half of the shadow, from which the other half may be drawn, as is shown by the figure; and this will give the shadow complete.

OBSERVATIONS.

I have given one example of the effect of light and shade on mouldings of different curvature: I shall endeavor to show the effect of light and shade also on many other examples, especially on the five orders of Architecture.

From what has been said on this subject, many practical and useful rules in shadowing may be deduced; but as I have far exceeded the bounds first assigned for this part, I must end with observing, that, from a consideration of the foregoing examples, the shadows of all objects, however complicated, may be found, as every object may be considered as compounded of prisms, cylinders, spheres, and annuluses;

Fig. 1.

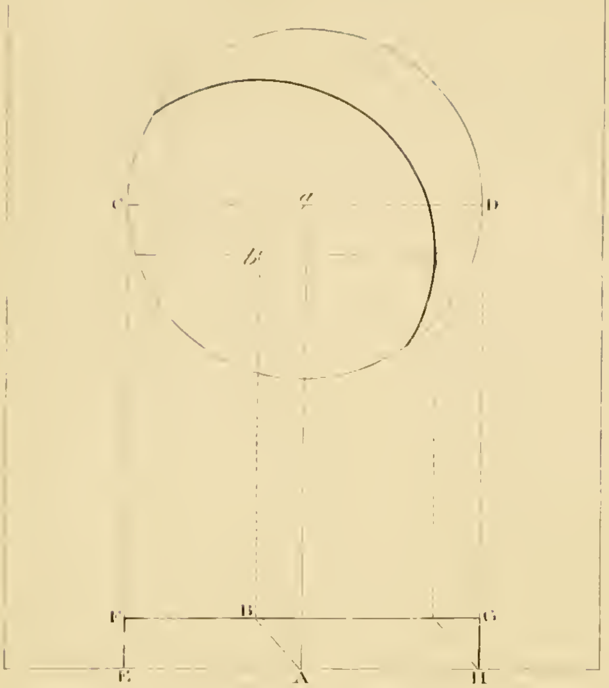


Fig. 2.

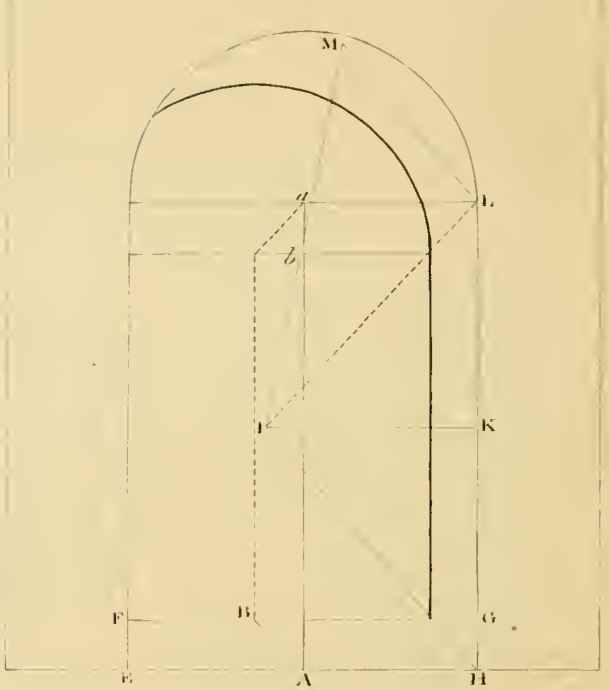


Fig. 3.

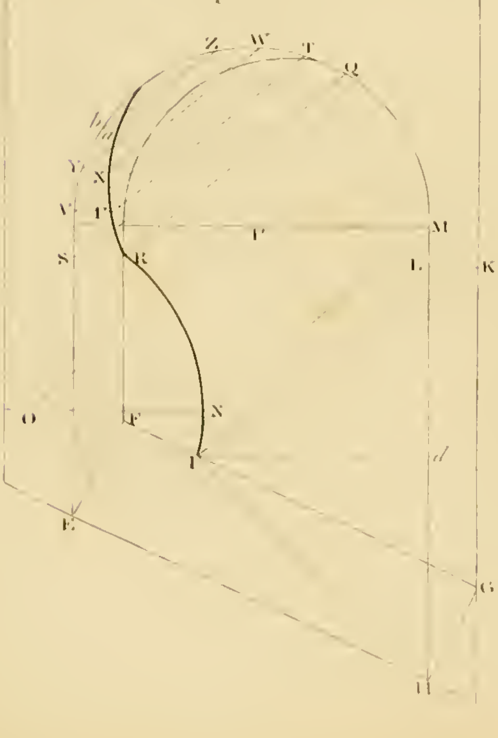
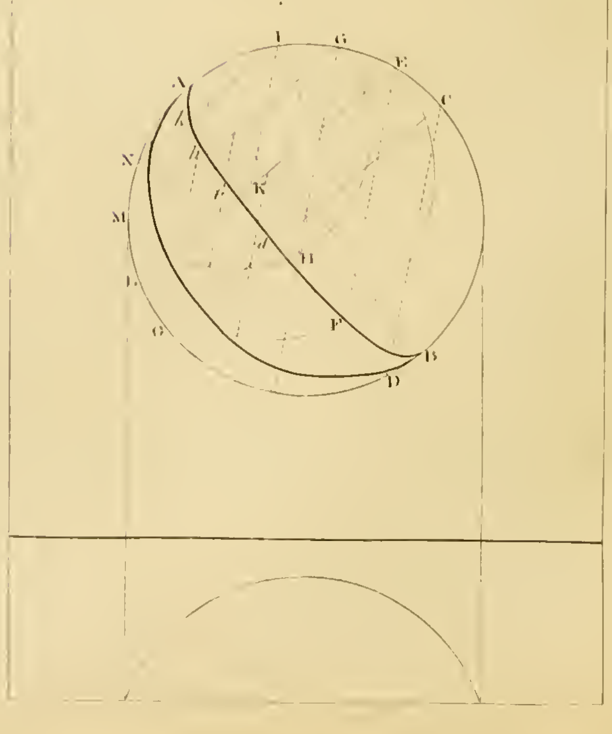


Fig. 4.



therefore, each part being projected separately, according to the rules for its particular kind of figure, the projection of all the shadows in that object will be completed.

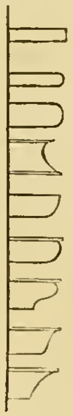
Although I have given correct methods for shadowing, I have no reason to think that the artist will always be at the trouble to project his shadows, for as drawings, in general, are shadowed to an angle of forty-five degrees, and as I have made choice of that angle, he will still find these examples to be his only guide in practice, as all the forms will be sufficiently near when copied by the eye and drawn by the hand of a judicious artist.

Note. — The treatise on shadows, like the preceding, has not been changed, but has been inserted in the form and manner in which it came from the author's pen. We should have been pleased to have inserted a few plates, to elucidate more fully the effect of light and shade upon different objects; but as this could not be done without swelling our volume to a much larger extent than was at first designed, we have given the original as it was in the previous editions. For those who may wish for a more extensive knowledge of shadows, we would refer them to Gwilt's Shades and Shadows, as being one of the clearest and most comprehensive works on the subject with which we have ever met. — Editors.

MOULDINGS.

Although, as observed in the Introduction of this work, (to which the student is referred,) the shaft of a column may not admit of any ornament on its body, yet in the base and capital various ornamental parts are introduced, which are called mouldings, because they are always of the same shape, as if they proceeded from the same mould or form. Mouldings are generally divided into Grecian and Roman, with reference to the existing remains of the architecture of those nations. The difference consists in this, that the Romans usually employed segments of circles in their ornaments, while the Greeks often introduced parts of an ellipsis, or some other section of a cone, varying from the circle.

The regular mouldings are variously disposed in different orders, and may reasonably be supposed to have had their origin in the ingenuity of man rather than in any essential necessary law in nature or art. The annexed figure represents their form and character.



The fillet, listel, annulet, or square.

Astragal, or bead.

Torus, or tore.

Scotia, trochilus, mouth, or casement.

Echinus, ovolo, or quarter round.

Grecian echinus.

Inverted cyma, talon, or ogee.

Cyma recta, or cymatium.

Cavetto, or hollow.

Of these, the Roman ovolo and cavetto are never found in Grecian architecture, nor the Greek echinus in that of the Roman; the rest they possess in common.

DEFINITIONS.

1. Mouldings are figures composed of various curves and straight lines.

If the mouldings are only composed of parts of a circle and straight lines, they are called *Roman*, because the Romans, in their buildings, seldom or never employed any other curve for mouldings than that of a circle; but if a moulding be made part of an ellipsis, or a parabola, or a hyperbola, the mouldings are then in the Grecian taste.

Corollary. — Hence it appears that mouldings in the Greek taste are of a much greater variety than those of the Roman, where only parts of circles are concerned.

Mouldings have various names, according to the manner in which they are curved.

2. The straight-lined part under or above a moulding, in general, is called a *fillet*.

3. If the contour of the moulding be convex, and a part of a circle, equal to or less than a quadrant, then the moulding is called a *Roman ovolo*, or an *echinus*, such as Fig. B, plate 26.

4. If the contour of the moulding be concave, and equal to or less than a quadrant, it is called a *cavetto* or *hollow*, such as Fig. D, plate 26.

Corollary. — Hence, a cavetto is just the reverse of an ovolo.

5. A bead is a moulding, whose contour is simply a convex semicircle.

6. If the contour be convex, and a complete semicircle or a semi-ellipsis, having a fillet above or below the moulding, it is called a *torus*, as Fig. A, plate 26.

Corollary. — Hence, a torus is a bead with a fillet, and is more particularly distinguished in an assemblage of mouldings from a bead, by its convex part being much greater.

7. If the contour of a moulding be a concave semi-ellipsis, it is called a *scotia*, as Fig. 2, No. 2, plate 28.

8. If the contour be convex, and not made of any part of a circle, but of some other of the conic sections, having a small bending inwards towards the top, the moulding is called a *Grecian ovolo* or *echinus*, such as Fig. 1, Nos. 1, 2, 3, 4; Fig. 4, Nos. 1, 2, and 3, plate 29.

9. If the contour be partly concave and partly convex, the moulding in general is called a *cimatium*, such as Fig. 2, Nos. 1 and 2; Fig. 3, Nos. 1 and 2, plate 29.

10. If the concave parts of the curve project beyond the convex part, the cimatium is called a *cima recta;* such as Fig. 2, Nos. 1, 2, and 3, plate 29.

11. If the convex part project beyond the concave, the cimatium is called a *cima reversa* or *ogee*, as Fig. 3, Nos. 1, 2, and 3, plate 28.

12. The bending or turning inwards of a small part of the convex curve of a Grecian moulding is, by workmen, called a *quirk*.

ROMAN MOULDINGS.

Plate 26.

To describe an ovolo in the Roman taste; the projections at a and b being given at each extreme of the curve.

Figs. A, B, and C. Take the height of the moulding; on the points a and b, as centres, describe an arc at c; on c, as a centre, with the radius $c\ a$ or $c\ b$, describe the arc $a\ b$, and it will be the contour of the moulding required.

To describe a cavetto, having the extremes of the curve.

Fig. D. The cavetto is described in the same manner, but on the opposite side.

To describe a hollow, to touch with two straight lines, $b\ d$ and $d\ a$, one of them at a given point a.

Figs. E and F. Let d be the point of their meeting; make $d\ b$ on the other line equal to $d\ a$; from the points a and b draw perpendiculars to each of the lines $d\ b$ and $d\ a$, meeting at c; on c, as a centre, with the radius $c\ b$ or $c\ a$, describe an arc $b\ a$, and it is done.

To describe a cima recta, the projections at a and b being given.

Fig. G. Join $a\ b$; bisect it at e; then on the points a and b describe arcs meeting each other on the opposite sides at c and d; on the points c and d, with the same radius, describe the opposite curves $a\ c$ and $e\ d$, and it is done.

Fig. H. The *cima reversa* is described in the same manner, but in an opposite direction.

To describe a torus.

Fig. I. Bisect the diameter at a; on it, with the radius, describe a semicircle, and it is done.

Fig. J is a semi-hollow.

Fig. K is a bed mould.

Fig. L is an ogee and bead.

GRECIAN MOULDINGS, COMPARED WITH THOSE OF THE ROMAN, TO SHOW THE DIFFERENCE OF THEIR FORM AND APPLICATION.

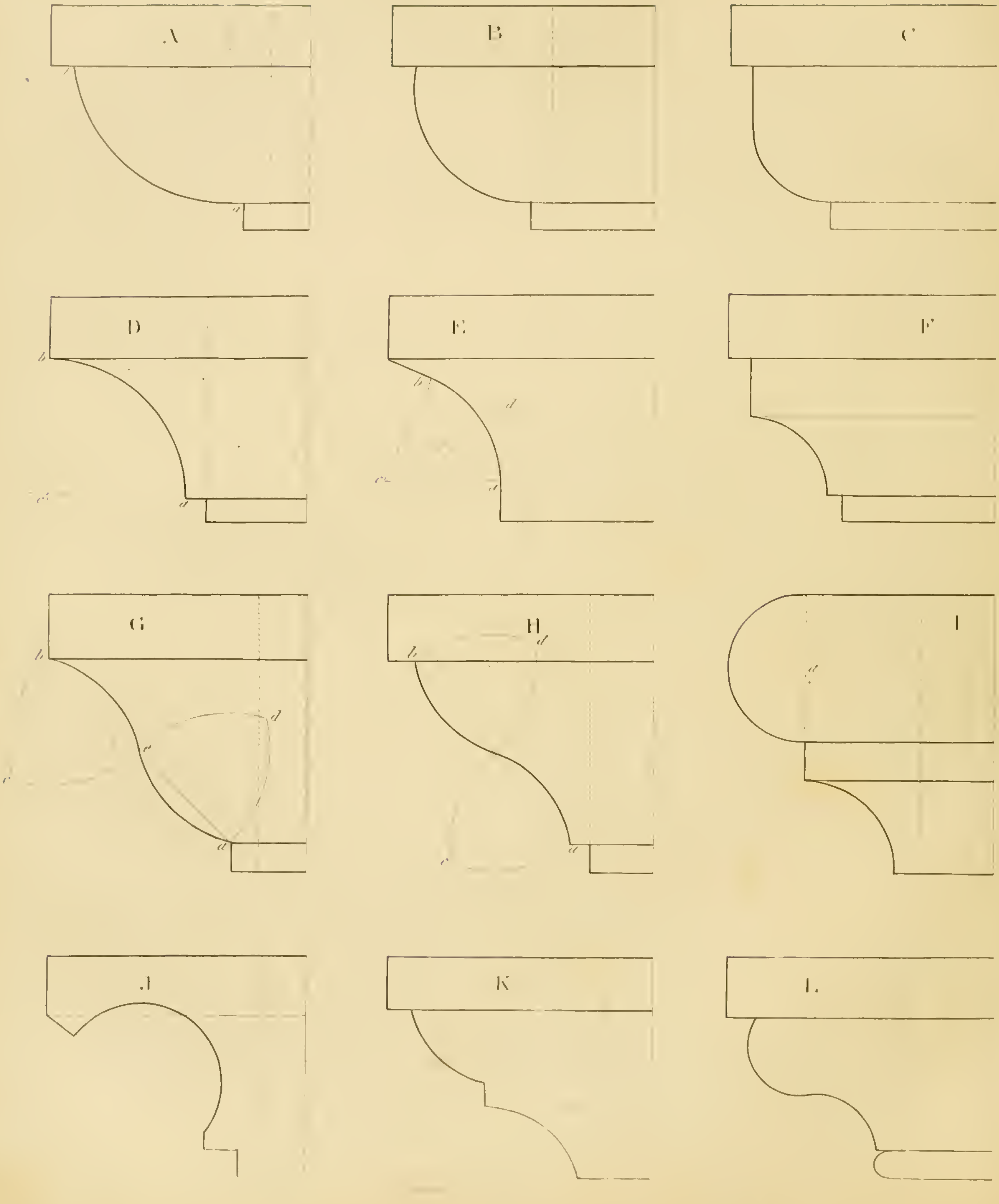
I. *Of a Bead.* — This moulding is similar in both Greek and Roman architecture.

II. *Of the Torus.* — The torus in most cases is similar to a bead: it is always so in Roman architecture, but not always in Grecian, as may be seen in various examples where the contour of the moulding is elliptical. The bases of the columns of the temple of Minerva Polias, and also the bases of the columns on the monument of Lysicrates, are instances of the elliptical forms of toruses.

III. *Of the Ovolo, or Echinus.* — The Greek ovolo differs greatly from that of the Roman: its contour is generally a part of the ellipsis; in some cases it is hyperbolical, and even in some a straight line; the elliptical ovolo is always used in cornices, architraves, and likewise in all mouldings projecting from plain surfaces. It is also to be met with in the capitals of columns.

Of such forms are the echinus of the capitals of

ROMAN MOULDINGS



the Doric portico at Athens, the temple at Corinth, and the temple at Pœstum, in Italy, which are all elliptical; but the hyperbolical form is oftener to be met with in the capitals of Athenian buildings than any other.

Of such are the echinus of the capitals of the temples of Minerva and Theseus, and also the capitals of the columns of the Prophylea, or grand entrance into the citadel. These are all Athenian buildings, which were erected during the administration of Pericles; and the portico of Philip, King of Macedon, is an instance in which the echinus is in a straight line.

In Roman architecture, the echinus is always some part of a circle, never exceeding a quadrant, but often less.

IV. *Of the Cavetto.*— The cavetto is the same both in Roman and Grecian architecture, except in its application. There is not an instance to be met with in Greece * where the crown moulding is a cavetto, but there are many in the Roman.

V. *Of the Doric Cimatium.*— This moulding is constantly used in Greek buildings, under the fillet of a finishing or crown moulding; but in Roman buildings, there are no instances whatever of any such moulding.

VI. *Of the Cima Recta.*— This moulding is nearly of the same form, both in the Grecian and Roman architecture, and is also applied for the same purpose in both.

VII. *Of the Cima Reversa.*— This moulding is nearly similar in the Grecian and Roman architecture, and is, in general, applied under the fillet of the crown moulding of the cornices of Roman buildings; but is never so applied in Greek buildings, one instance excepted, which is the Portico of Philip, King of Macedon.

THE EFFECT OF GRECIAN MOULDINGS, COMPARED WITH THE ROMAN OF THE SAME KIND.

I. *Of the Ovolo.*— The bending or turning inwards of the upper edge of the Grecian ovolo causes, when the sun shines on its surface, a beautiful variety of light and shade, which greatly relieves it from plane surfaces; and if it be entirely in shadow, but receive a reflected light, the bending or turning inwards at the top will cause it to contain a great quantity of shade in that place, but softened downwards round the moulding to the under edge.

In the Roman ovolo there is no turning inwards;* at the top, therefore, when the sun shines on its surface, it will not be so bright on its upper edge as the Grecian ovolo; nor will it cause so beautiful a line of distinction from other mouldings which it is combined with when it is in shadow, and when lighted by reflection.

II. *Of the Cima Reversa.*— In the Greek *cima reversa*, the turning in of its upper edge, and the turning out of its under edge, will cause it, when the sun shines, to be very bright on these edges, which will greatly relieve it from other perpendicular surfaces when combined together; and when it is in shadow, and lighted by reflection, the inclination of the upper and under edges will also make a strong line of distinction on both edges, between it and other mouldings or planes connected with it; whereas the upper and under edges of the Roman *cima reversa* † being perpendicular to the horizon, the lightest place on its surface will not be brighter than a perpendicular plane surface, nor will it be better relieved in shadows than perpendicular plane surfaces also in shadow.

THE EFFECT OF GRECIAN MOULDINGS, COMPARED WITH ROMAN MOULDINGS OF A DIFFERENT KIND, BUT IN SIMILAR SITUATIONS.

I. *Of the Greek Ovolo, compared with the Roman Cavetto, when used as finishing Mouldings.*

The upper mouldings, in all the remains of antiquity, are either entirely destroyed or much defaced. It is certain, that if ovolos, which are strong mouldings, had been employed instead of cavettos, ‡ many of them would have been almost entire; and as the degrees of light and shade on the surface of the ovolo,

* There are some out of Greece; but of these there are few instances which may not be looked on as deviations from the established methods that were used by the Greeks.

* That is to say, the upper edge of the moulding does not recede from a plane touching its surface, and perpendicular to the horizon.

† There are some instances in Roman buildings where the cima reversa is turned inwards at the top, and outwards at the bottom; but this seldom occurs, except there is not sufficient projection to its height.

‡ Some authors say, that the cima recta and cavetto were always used as finishing mouldings; but it is quite the reverse; for in the antique buildings now remaining in Greece there is not a single instance where a cavetto is used for the upper member of a cornice; but in Doric buildings, the cornice always finishes with an ovolo; and in buildings of the Ionic and Corinthian orders, they are finished with cima rectas.

whether from sunshine or from any other light, is beautiful and soft, the shadow of the cavetto from sunshine is very hard, and will not contain so great a variety of light and shade on its surface; it will, therefore, be less pleasing to the eye.

II. *The Doric Cimatium used by the Grecians under the Fillet of the Crown Moulding, compared with the Cima Reversa in the same Situation.*

The front of the Doric cimatium is a convex elliptical curve, and is sunk at the upper edge in the manner of a Grecian ovolo; therefore, the light and shade on its front will be nearly similar to an ovolo; and as the sinking upwards behind the front will cause it to contain a quantity of shade, — which will form a line of separation from the corona, and, consequently, make it appear more distinct at a distance, but the Roman cima reversa, being so very flat, would not be well relieved, — its profile would be lost entirely at a distance.

MODERN MOULDINGS.

I have given several modern designs for mouldings, not that in my own opinion they are more tasteful than the Grecian or Roman, but that by combining them it affords a greater variety; and, as some are fond of new things, they may be preferred.

Plate 27.

A is a cima recta. B is a cima reversa, or ogee. C is a bed mould. These differ from the Roman only in their curves being more graceful, but are formed on the same principle.

D, E, F, G, H, I, J, K, and L are formed on the principle of the Grecian, with a slight alteration in their curves.

GRECIAN MOULDINGS.

Plate 29.

To describe the Grecian echinus or ovolo; the tangent A B, at the bottom, the point of contact A, and the greatest projection of the moulding at C being given.

Fig. 4, No. 2. From A, draw A D E perpendicular; through C draw C D parallel to the tangent B A, cutting A E at D; make D E equal to A D then will D be the centre of an ellipsis, and C D and D A will be two semi-conjugate diameters, from which the ellipsis may be described by plate 6, Geometry.

Fig. 4, No. 1. This figure is described in the same manner, and shows a greater projection, the tangent being also taken in a higher position.

The same things being given, to describe the moulding nearly, when the point of contact A is at the extremity of the transverse axis.

Fig. 4, No. 3. From A, draw A D E perpendicular to the tangent B A; parallel to it draw C G, cutting the tangent A B at G; also, through C draw C D parallel to the tangent A B, cutting A D E at D, the centre of the ellipsis, for which D C and D A are the semi-transverse and semi-conjugate axis, and proceed as before.

Plate 28.

The semi-transverse and semi-conjugate axis being given, to describe the moulding.

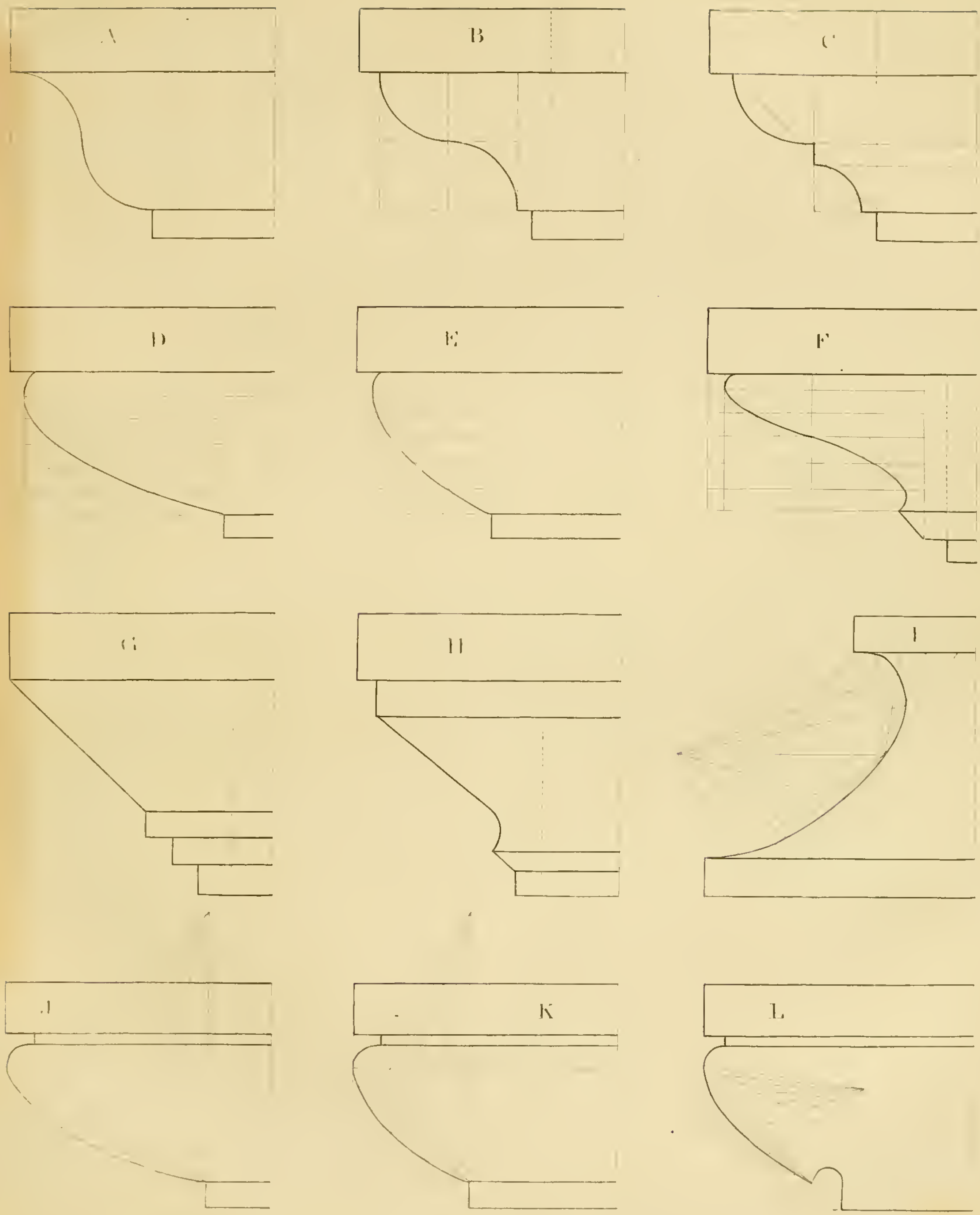
Fig. 1, Nos. 2 and 3. Proceed as in plate 6, Geometry, and you will have the contour of the moulding required.

To describe the cima recta, the perpendicular height, H L, being given, and its projection, L I.

Fig. 2, No. 1. Complete the rectangle I L H F, and divide the whole rectangle into four equal rectangles; then inscribe the concave quadrant of an ellipsis in the rectangle I K C B, and a convex quadrant in the rectangle C G H D, and it is done.

To describe a cima reversa, the point A being nearly the greatest projection at the top; D the extremity of the curve at the bottom; and D C a line parallel to a tangent, at the point of junction of the opposite curve.

Fig. 3, No. 3. Draw A C at right angles to C D, cutting C D at C, and complete the rectangle A C D E; then proceed as before, but in a contrary direction, and you will have the contour required.


A
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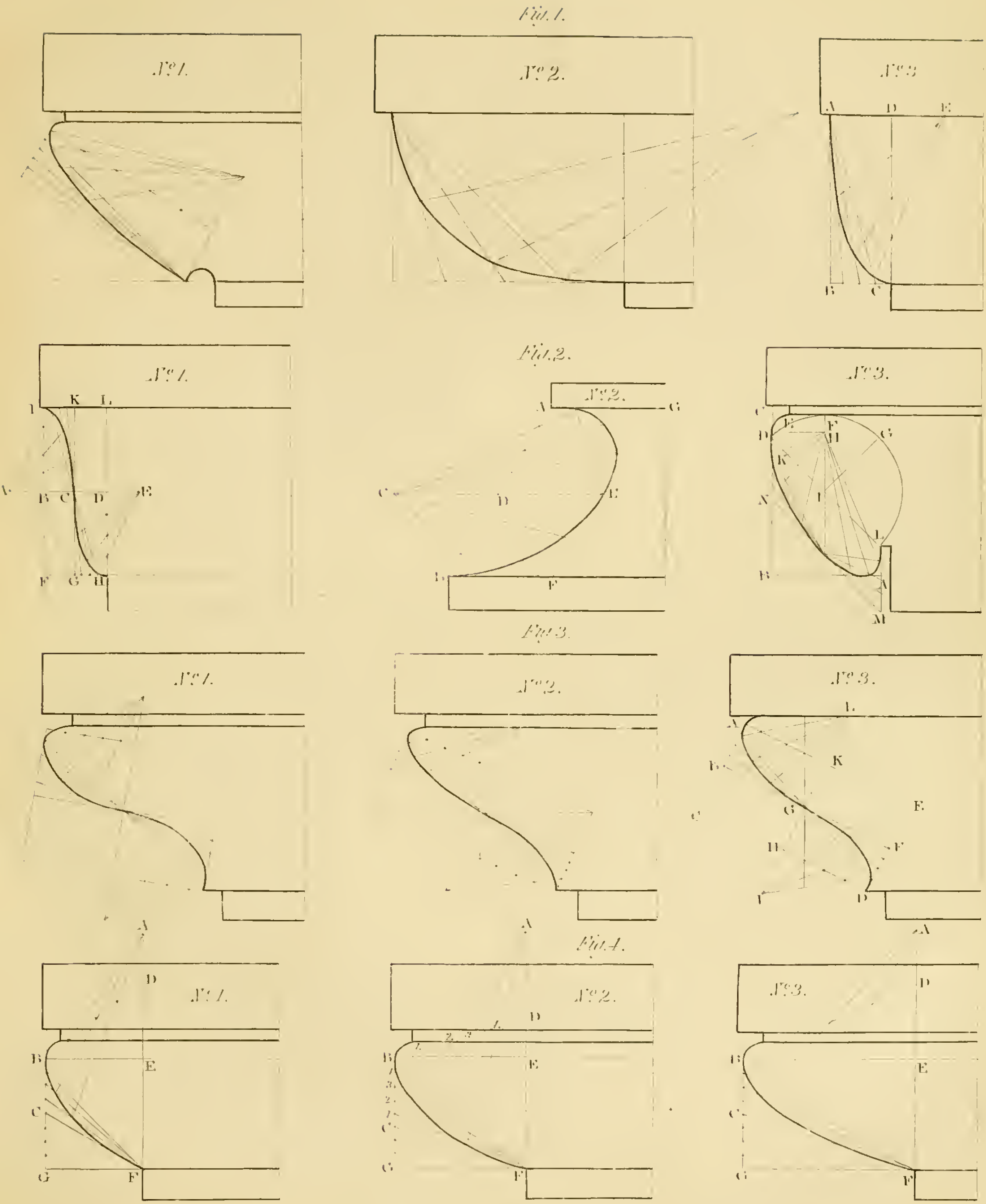
Fig. 1.
No. 1.
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Fig. 2.
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Fig. 1.

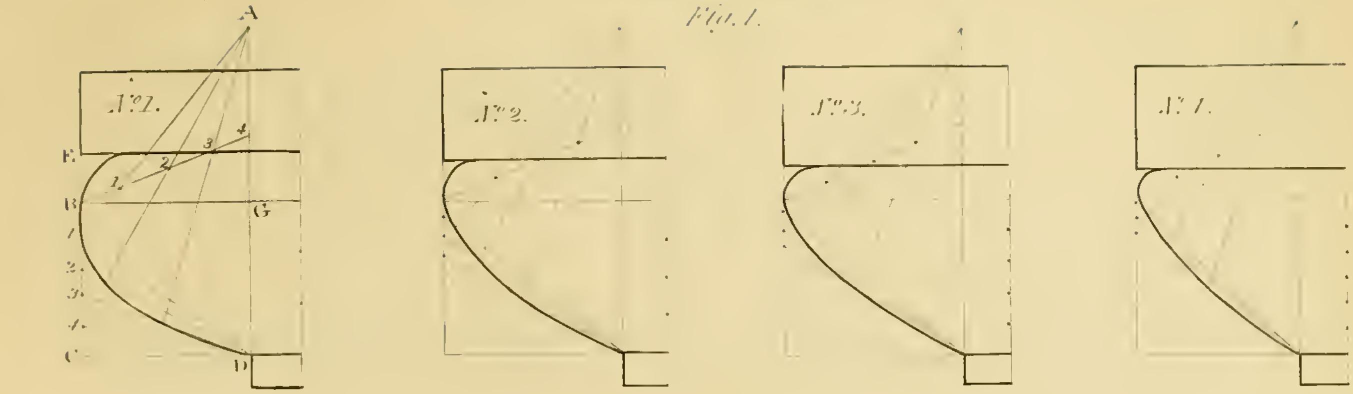


Fig. 2.

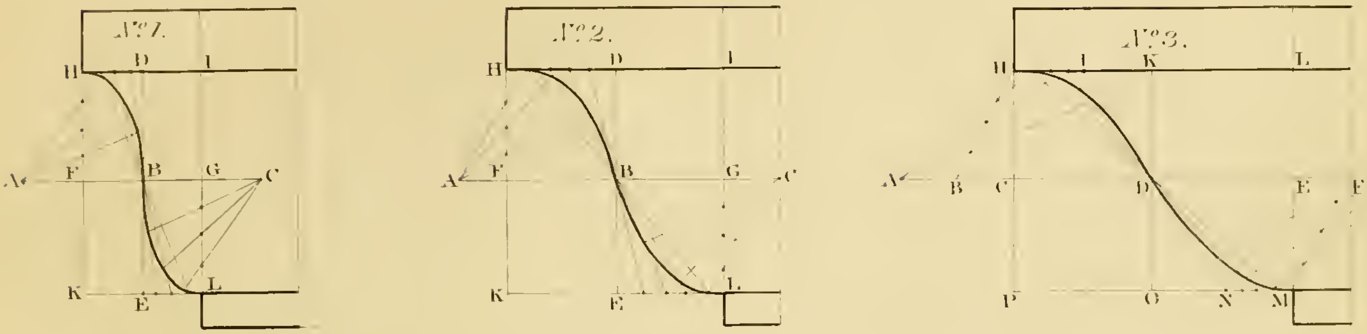
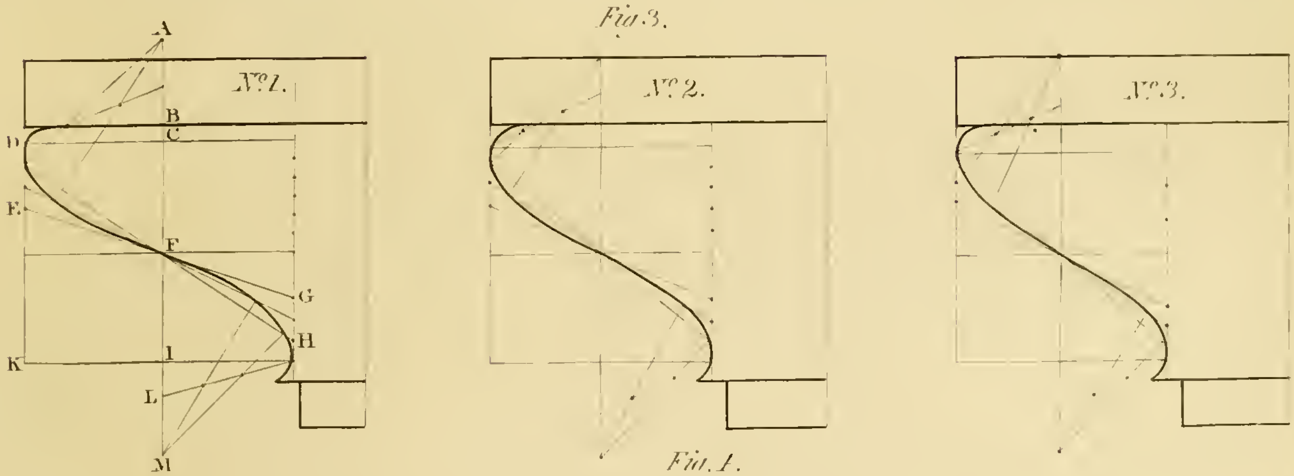


Fig. 3.



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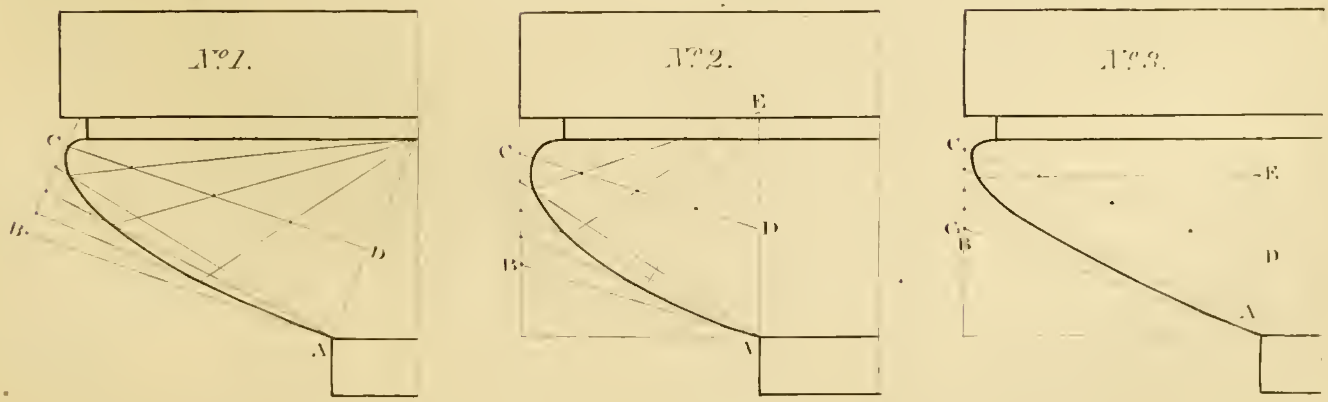
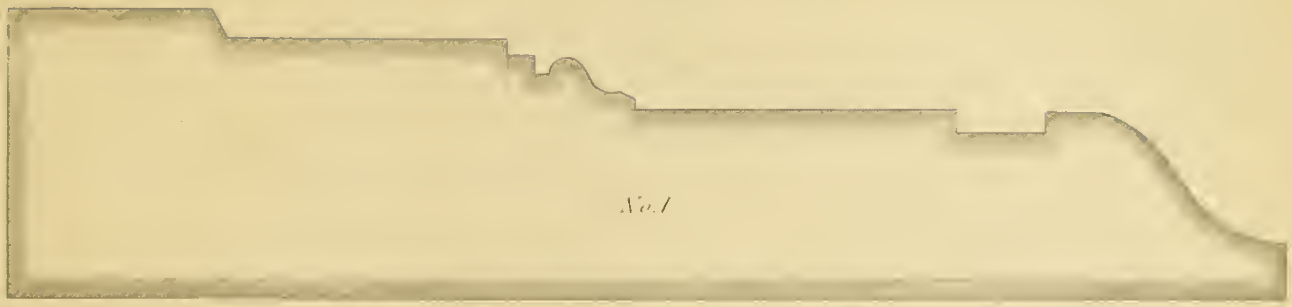
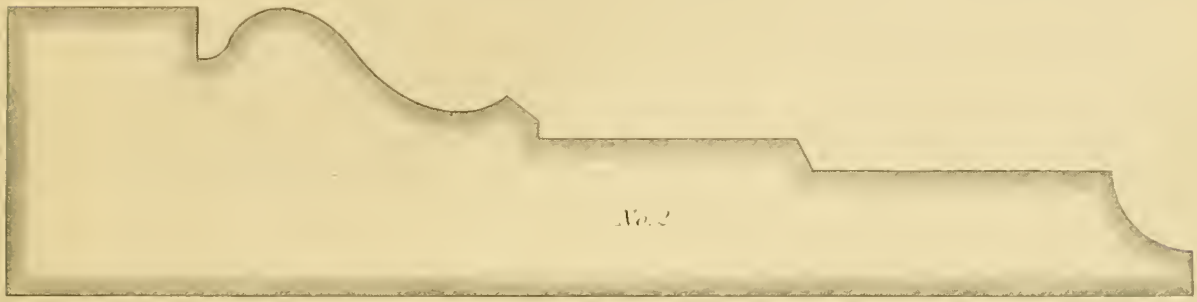
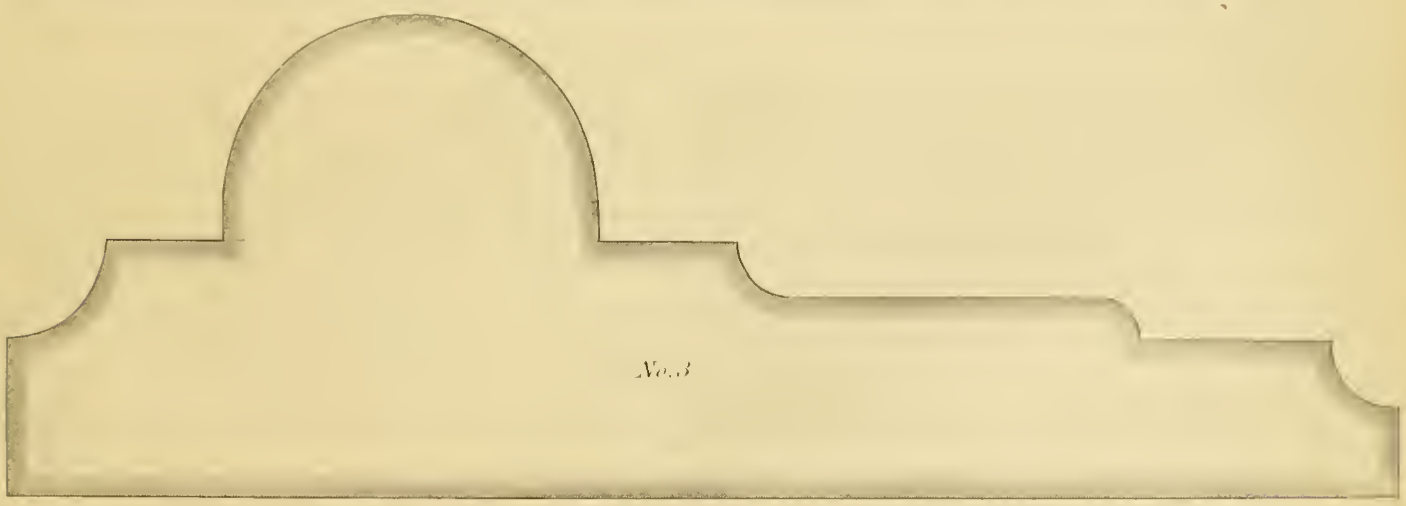


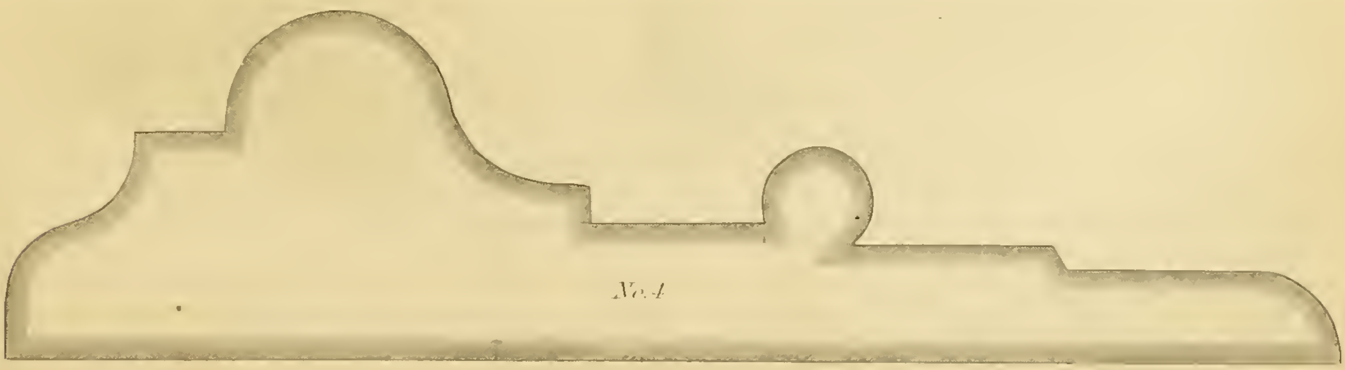
ARCHITRAVES FOR DOORS AND WINDOWS.

Full size.









To describe an echinus having the depth of the moulding C D, the greatest projection at D, and to be quirked at the top and bottom.

Fig. 2, No. 3. Complete the rectangle C B A, and proceed as in plate 6, Geometry.

To describe a scotia.

Fig. 2, No. 2. Join the ends of each fillet by the right line A B; bisect A B at D; through D draw C D E parallel to the fillets, and make C D and D E equal to the depth of the scotia; then will A B be a diameter of an ellipsis, and C E its conjugate. Proceed as in plate 6, Geometry.

How to describe Grecian mouldings, whether elliptical, parabolical, or hyperbolical; the greatest projection at B being given, and the tangent C F at F, the bottom of the moulding.

Fig. 4, Nos. 1, 2, and 3. Draw G F a continuation of the upper side of the under fillet; through B draw B G perpendicular to B F, cutting it at G, and the tangent F C at the point C; also, through B draw B E parallel to G F; and through F draw F D E A parallel to G B, cutting B E at E; make E A equal to E F, E D equal to C G, and join B D; then divide each of the lines B D and B C into a like number of equal parts; from the point A, and through the points 1, 2, 3, 4, in B C, draw lines, cutting the former, which will give the points in the curve.

If the point C, where the tangent cuts the line B G, be less than one half of B G, from G the moulding will be elliptical, as in Fig. 4, No. 2.

If G C be one half of B G, then the moulding is parabolical, as in Fig. 4, No. 1.

If G C be greater than half of B G, then the moulding is hyperbolical, as in Fig. 4, No. 3.

By this means you may make a moulding to any form you please, whether flat or round.

[On plate 30 will be found four designs for architraves, for the finish of doors and windows, full size. These are substituted for plates 83 and 84 of the last edition, as being more in keeping with the taste of the times, &c. — EDITORS.]

THE ORDERS.

The term *order* seems to sustain the same relation to architecture that the term *harmony* does to music, or the ancient term *ordonnance* to painting. It is, in fact, no more nor less than an assemblage of parts and mouldings, so disposed as to give an effect at once pleasing to the eye, and proportioned and adapted to the office each has to perform.

Vitruvius, who was nearly, if not the first writer on architecture who flourished in the first century after the birth of Christ, expresses the idea as follows: "It is an apt and regular disposition of the members of a work separately, and a comparison of the universal proportion with symmetry." This, in his work, (chapter 2d,) he calls *ordonnance*. Scamozzi, the son of an architect, and himself one of the old masters, the rival of Palladio, and who after the death of that artist, in 1580, had no competitor, is, we believe, the first of the ancient writers that has given us what may be termed the description of an order. He observes in his book, (2d chapter, 2d part,) "that it is a kind of excellency which infinitely adds to the shape and beauty of buildings, sacred or profane." He seems to have attempted to convey the same idea as the author before quoted, which idea is comprehended in the terms *propriety* and *harmony*. Having now given the idea which the ancients would seem to have us entertain by the Latin word *order*, we will proceed to illustrate more fully the composition and use of the orders. First, then, an order is composed of two parts, viz., the column and the entablature; these are again each divided into three other parts, which parts are composed of an assemblage of mouldings, each respectively proportioned and adapted to the order of which it is a part. The parts of the entablature are called the architrave, frieze, and cornice; those of the column are the base, shaft, and capital, as

may be seen on plate 50. These are again subdivided into other parts, as will be seen by the description of the respective orders. The species of orders are five in number — the Tuscan, Doric, Ionic, Corinthian, and Composite; each is a composition peculiar to itself, and is calculated to produce the expression it is intended to possess, viz., strength, grace, elegance, and richness. The orders above named rightly understood, and correctly applied, are the foundation upon which architecture has long rested as an art. The oldest of these is the Doric, the next the Ionic, and the last the Corinthian. The Tuscan is said to have been invented by the inhabitants of Tuscany; and Vitruvius has first given it a name and placed it in his book, a copy of which is shown on page 31; but he does not inform us of a single building on which it has been employed, and as no examples exist to warrant the belief of its frequent use in his day, we are led to suppose that its rustic plainness did not suit the Roman taste of his time. It has, however, received the approbation of the principal masters who have succeeded him, and is now ranked with the regular orders. The Composite is a Roman invention, and has been termed by Sir Henry Wotton, in his Parallel of Ancient Architecture with the Modern, the *compounded* order. It is composed of parts of the other orders, but principally of the Ionic and Corinthian. The proportion of the parts of the orders are as various as the examples — no two authors agreeing. In the examples given, the parts are figured, as will be seen; and the proportion assigned to each, as the example or author has directed explanations of the orders more in detail, will be found attached to them under their respective heads. — Eds.

TUSCAN ORDER.

The Romans added the Tuscan, or Etruscan, to the three Grecian orders, as they subsequently did the Composite. The idea of the Tuscan is undoubtedly derived from the Doric order, from which it differs, according to the view taken of it by Aldrich, as much as the appearance of an inhabitant of the country does from one of a city. There is extant no ancient specimen of it with an entablature. It is the first of the Italic orders, and is called Tuscan, as having been originally employed by that ancient people, once powerful in Italy. "Vitruvius speaks of it as rustic even to deformity; nor were the later masters more favorable to it, except Palladio." Having no complete example from antique buildings, that which is given in this work is taken from the description by Vitruvius.

Plate 31.

From Vitruvius, with the Proportion of the Parts in Numbers.

We have no complete example of this order remaining from antique buildings; and all that we know of it is from the description by Vitruvius, from which this example is taken, and is, therefore, the only standard.

The proportions of the parts are exhibited by equal divisions on the plate.

That celebrated building, St. Paul's, Covent Garden, is the only true specimen there is of the Tuscan order in England. It may be adapted with great propriety to market-places, as the simplicity of its parts and the extraordinary projection of the cornice render it suitable for that purpose.

Fig. 1. Elevation of the order, from Vitruvius.

Fig. 2. The ichnography of the mutules in the cornice.

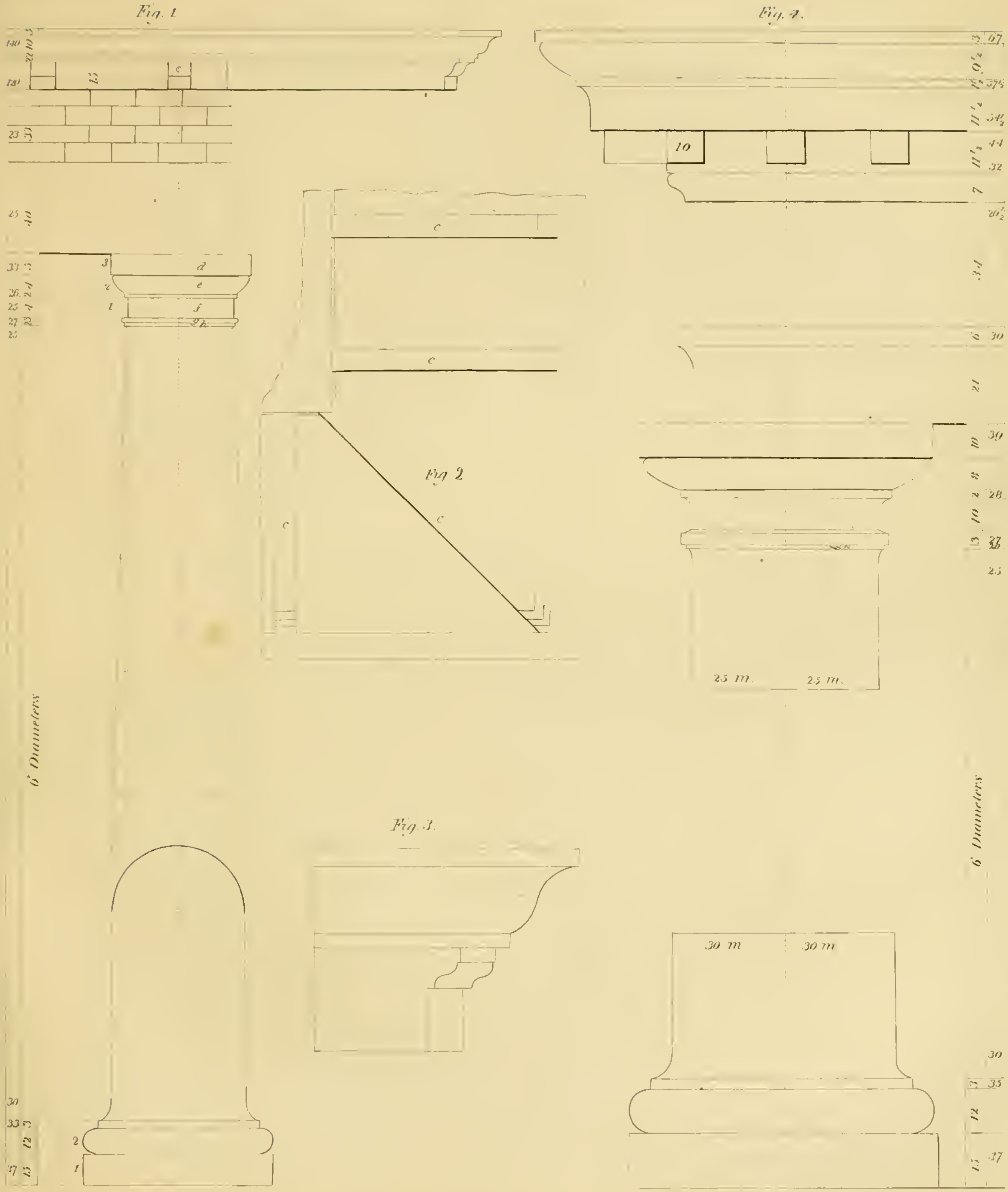
Fig. 3. Profile of the upper part of the cornice.

The column is seven diameters high; the base and capital are each half a diameter; the base is divided into two equal parts, one of which is given to the plinth, the other to the torus and fillet; divide the capital into three equal parts, give one to the hypotrachelion, one to the ovolo and fillet, and the upper one to the abacus. The mutules in the cornice are to project one fourth of the length of the column.

Fig. 4. A modern example of the Tuscan order. with the proportional measures in numbers.

On plate 32, we have given a design for the regular Tuscan order. No example, except that on plate 31, is in any of the previous editions. The design here given is a composition from Chambers and Palladio. In his example of the Tuscan, Chambers has followed Vignola and Serlio, in omitting the break in the architrave, and making it consist of only two members. This, it is acknowledged, is according to the example given us by Vitruvius; but as liberty has been taken to adapt it to other times, there seems to be no excuse why the method pursued by Palladio should not be entitled to as much attention as that by Vignola. The majority of authors have approved the practice of the former; in the example we have composed, we have retained the bold and classic proportions, as given by Chambers, for the cornice, adding to it the architrave by Palladio. The column is according to that given us by Chambers, and it is, we believe, the most approved proportion with which

TUSCAN ORDER.



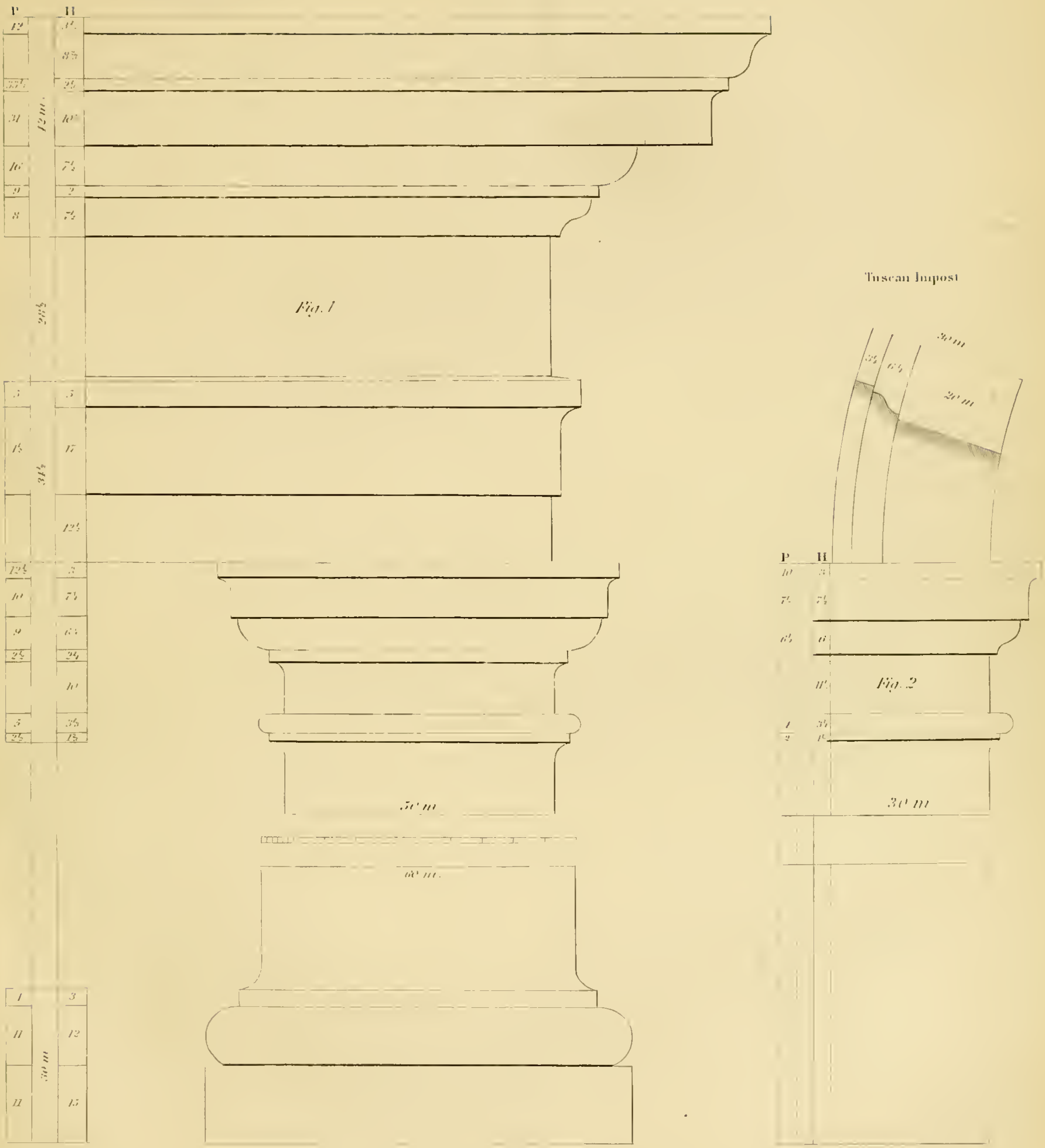


Fig. 1
Tuscan Impost
Fig. 2

we are acquainted. No. 1, on plate 32, is the order figured to a scale of minutes. No. 2 is the impost and archivolt of the same. — Editors.

ROMAN DORIC.

Some architects have maintained that the Doric order is unfit for sacred edifices, by reason of its irregularity. This opinion was held by Tarchesius, Pytheus, and Hermogenus. The latter, after having prepared marble materials for building a Doric temple, changed the order, and made it Ionic, dedicating it to Bacchus. The Doric order, however, is not deficient in grandeur, but an inconvenience arises in the distribution of the triglyphs and lacunaria; for it is necessary that the triglyphs should be placed over the middle quarters of the columns, and the metopes, which are between the triglyphs, must be as long as high; also, the triglyphs at the angles are placed at the extremities, and not over the middle of the columns; therefore, the metopes which are next the angular triglyphs will not be square, but longer by half the breadth of a triglyph. Some, who wish to make the metopes equal, lessen the extreme intercolumniation by half the breadth of the triglyph. However, the metope or the contracting of the intercolumniation is a defect. Though the ancients have been observed to neglect exact regularity in Doric buildings, it is shown in its proper place how far we ought to follow our masters.

The front of a Doric temple, where the columns are placed, is divided, if it be terastyle, into twenty-eight parts; if hexastyle, into forty-four. One of these parts will be the module, which, in Greek, is called *Embates*, and by which all the other parts are proportioned.

The thickness of the column must be two modules; the height, with the capital, fourteen; the height of the capital one module, the breadth two modules and a sixth. The height of the capital is divided into three parts, of which one is given to the abacus, with the cimatium; another to the echinus, with the annulets; and the third to the hypotrachelion. The columns are diminished as described on the plates.

The height of the epistilium, with the tenia and drops, is one module. The tenia has the seventh of a module, the length of a guttæ under the tenia coinciding with the perpendicular of the triglyphs. Their height with the regula is one sixth of a module. The breadth of the epistilium also answers to the hypotrachelion of the column.

On the epistilium are placed the triglyphs with the metopes, having the height of one module and a half, and the breadth in front one module. They must be so distributed that they may be over the centre of the columns at the angles, and two between each column. The breadth of the triglyphs is divided into twelve equal parts, of which the breadth of the femur in the middle will be two parts; then a channel is cut on each side of the femur, the breadth of each channel being equal to two parts. Next to the channels two other femurs are left, one on the right and the other on the left, each equal to the breadth of the middle femur, or two parts; then a part will remain next to the edge of each triglyph, which is to be cut away in the form of a semi-channel. On either side of this channels are sunk, as if imprinted by the elbow of a square. To the right and left of these another femur is formed. In the same manner, semi-channels must be sunk at the extremities. The triglyphs being thus disposed, the metopes are as high as long; on the angles, also, the semi-metopes are made half a module in width.

Thus all the errors arising from the wrong distribution of the metopes, intercolumniations, and lacunaria will be rectified.

The capitals of the triglyphs must have one sixth of a module. On these capitals is placed the corona, projecting a half and a sixth part of a module, having a Doric cimatium below, and another above. The corona, with the cimatiums, are half a module in thickness. In the under part of the corona, perpendicularly over the triglyphs and metopes, the guttæ in the mutules are so distributed that there may be six in length, and three in breadth. The spaces between the metopes being rather broader than the triglyphs, are either left plain, or carved; and at the edge of the corona a channel is cut, called *Scotia;* all the remainder, as the tympanum, the cima, and corona, are the same as in the Ionic order.

Concerning the diminution of the column, according to Vitruvius, he gave the following rule for all kinds of columns, the Tuscan excepted: —

The diminution of the top of the column at the hypotrachelion is thus regulated: If the column be not less than fifteen feet high, the thickness at the bottom is divided into six parts, and five of these parts are given as the thickness at the top.

" If the height is from fifteen to twenty feet, the bottom of the shaft is divided into six parts and a half, and five and a half of these parts make the

thickness of the column at top; and if from twenty to thirty feet, the bottom is divided into seven parts, and six of these make the diminution at the top. If it is from thirty to forty feet high; the bottom thickness is divided into seven parts and a half, of which six and a half is the measure of the diminution at the top. If from forty to fifty feet, it is divided into eight parts, whereof seven will make the thickness of the hypotrachelion at the top of the shaft. And if it is still higher, the same proportional method is observed; for, as a greater height causes them to appear more diminished, they are, therefore, to be corrected by an addition of thickness, beauty being the province of the eye, which, if not satisfied by the due proportion and augmentation of the members, correcting apparent deficiencies with proper additions, the aspect will appear coarse and displeasing.

Plate 33.

This plate shows the elevation of the Roman Doric, as given by Palladio.

Fig. 1. The elevation.

Fig. 2. The cornice inverted.

Fig. 3. The capital inverted.

Plate 34.

Elevation of the Doric Order from the Baths of Dioclesian, at Rome, with the Proportions in Numbers.

The cornice of this example is not Doric; it is too abundant with mouldings, and overcharged with enrichments.

The disposition of the triglyphs and metopes in the frieze is according to the rules of Vitruvius.

The capital is not Doric, but of another kind; nor could this composition be known to have the least resemblance to the Doric order, if the triglyphs in the frieze were omitted.

Fig. 1. The elevation of this example.

Fig. 2. A section of the column, showing the flutes.

ROMAN IONIC,

Plate 35,

Is the Roman Ionic as approved by Chambers, and is inserted to supply the place of plates 56 and 57 of the previous edition, which contained the example of the Temple of Concord, at Rome. This was a very singular example, which was, perhaps, the best authority the author had for introducing it. The cornice contains mutules resembling the Doric, and dentils as in the Ionic. The frieze and architrave are plain, with the exception of two breaks, the top one of which contains a cavetto or hollow. There is no band moulding to separate the frieze from the architrave. The capital is angular, voluted, and is not without merit; but the extreme plainness of the space between the cornice and the top of the capital, and the connection between the cornice and frieze, is so inelegant, that the anathemas of those who would have used it have been called down upon it, and it is now scarcely if ever used. The example given by Chambers is, perhaps, as good as any we have; and we have, therefore, inserted it to complete the Roman orders. Fig. 1 is the order, and figs. 2, 3, and 4 the details of the capital. — EDITORS.

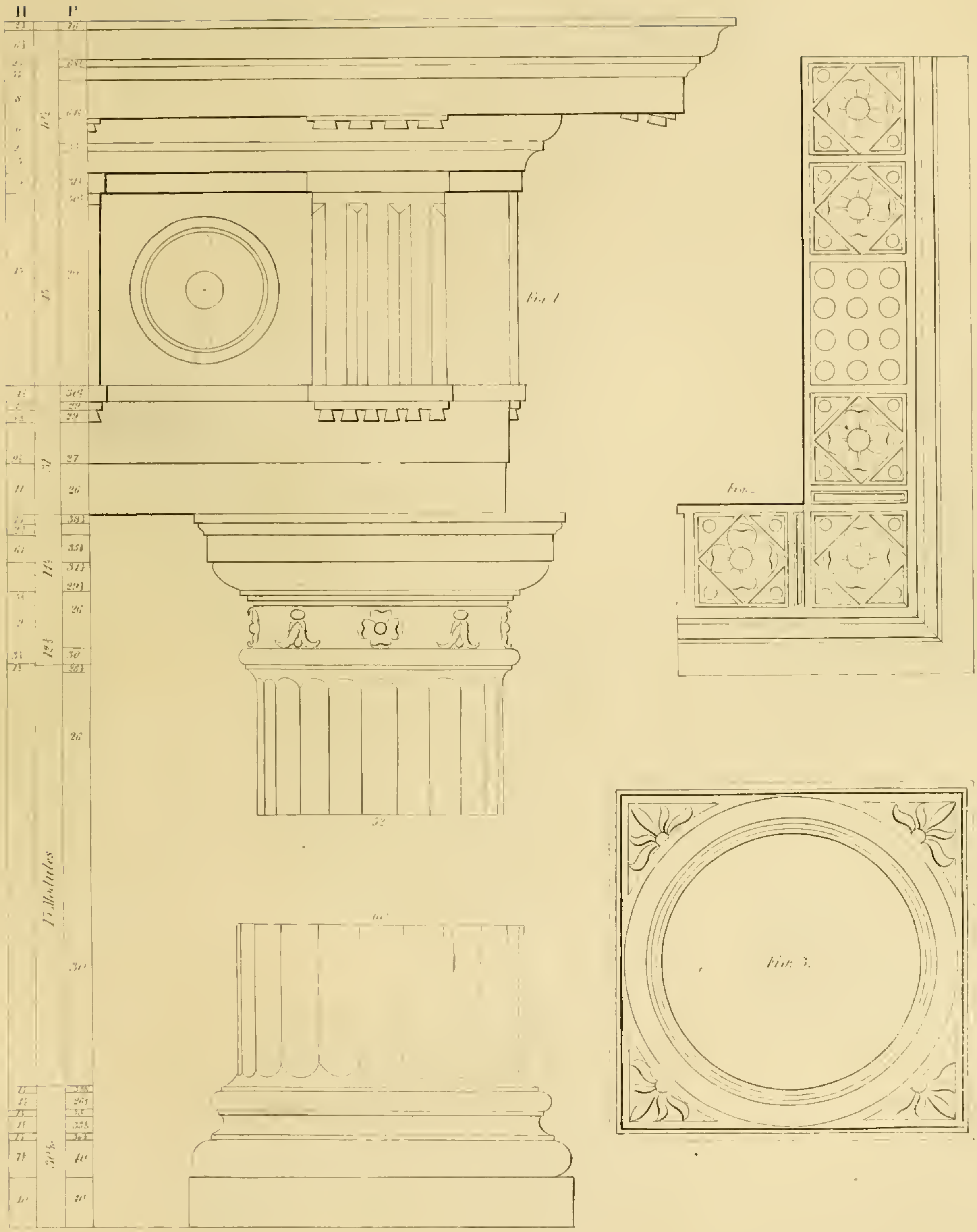
CORINTHIAN ORDER.

The Corinthian order took its rise in the flourishing days of Corinth, a celebrated city commanding the communication of the peninsula of Peloponnesus with the continent of Greece. It is generally regarded by writers on architecture as being more delicate than the Ionic, and is thought to resemble the graceful figure of a virgin. Among the ancients, it had much resemblance to the Ionic. According to Vitruvius, it imitated that order in every part but in the capital of the pillar. In the introduction to this work, we have alluded to the pretty Greek story told of the origin of the capital. Villapandus gives another equally dubious account of its origin; and Aldrich conjectures as more probable that, as the shaft of a pillar represents the trunk of a tree, so the tree being lopped, and sprouting again, furnished the hint for the design of this capital. But, however this may be, we believe it will be generally conceded that, in attempting too much, this order has deviated from the true simplicity of nature. It marked an age of luxury and magnificence, when pomp and splendor had become the predominant passion, but had not yet extinguished the taste for the sublime and beautiful; and in this, attempts were made to unite these characters.

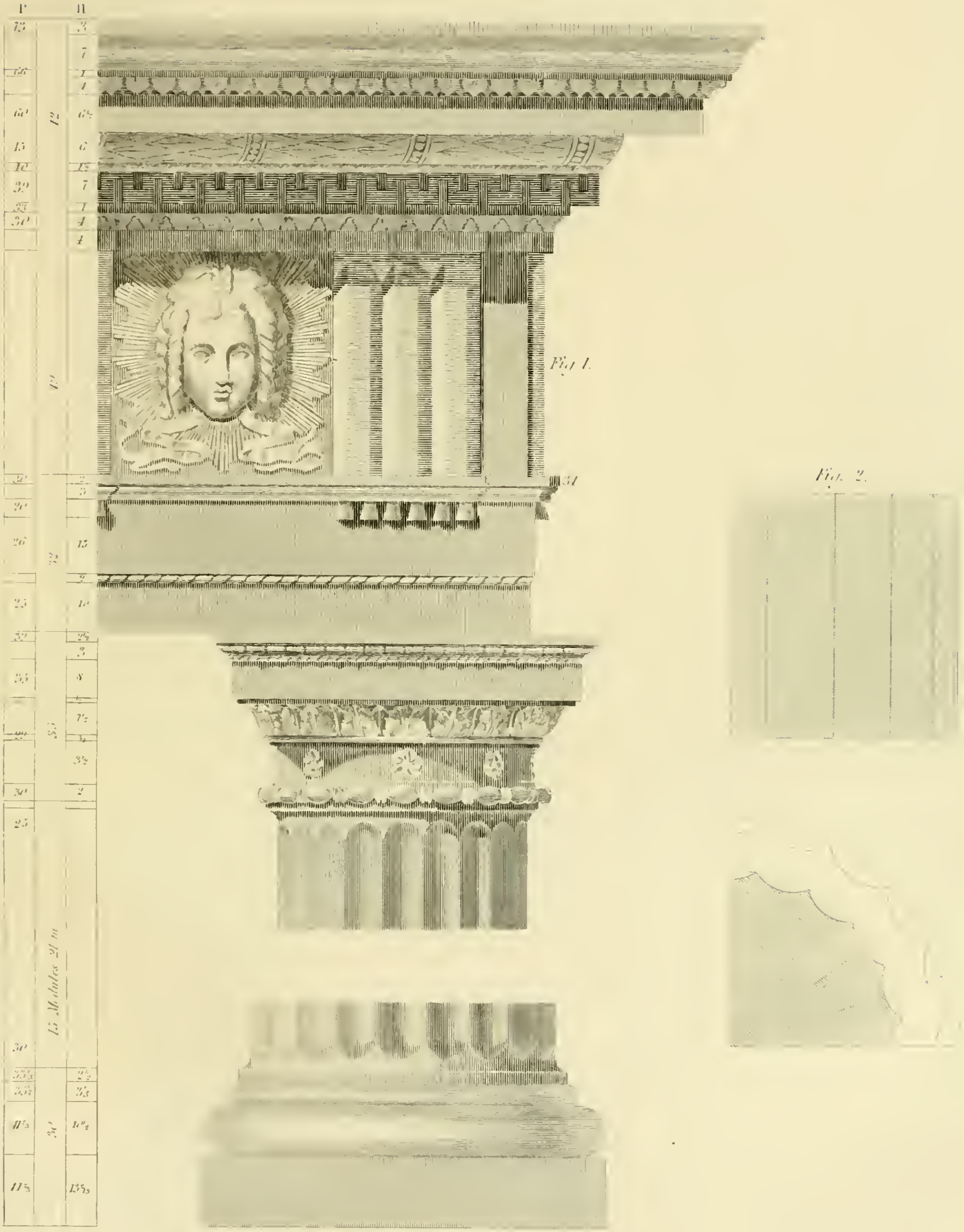
DEFINITIONS.

1. An order which has two annular rows of leaves in the capital, each leaf of the upper row growing between those of the lower row, in such a manner that a leaf of the upper row may be in the middle of each side or face of the capital, — and if between

From Andrea Palladio

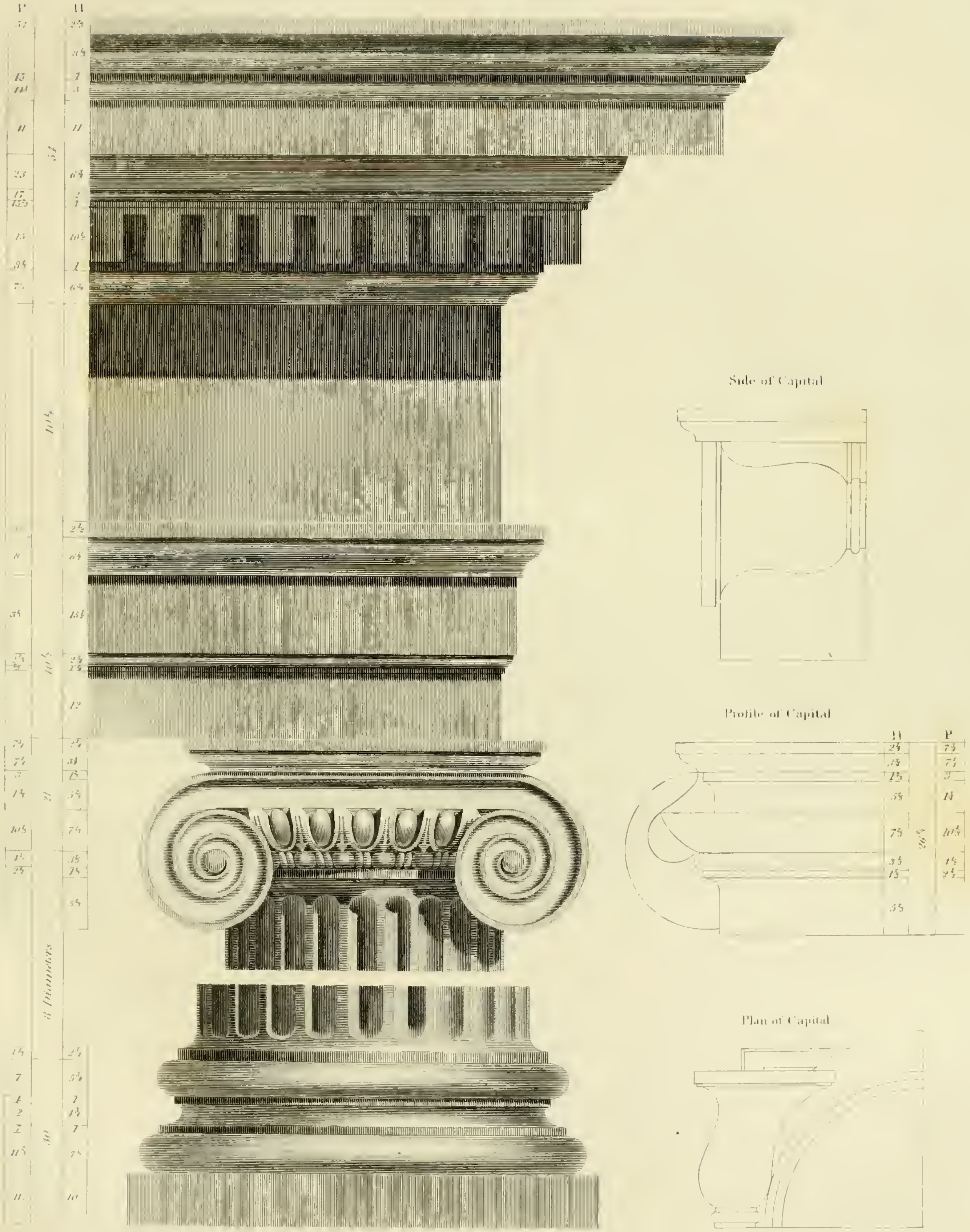


From the Baths of Dioclesian at Rome



IONIC ORDER,

according to Sir William Chambers.



From the Temple of Jupiter Stator at Rome

Fig. 1.

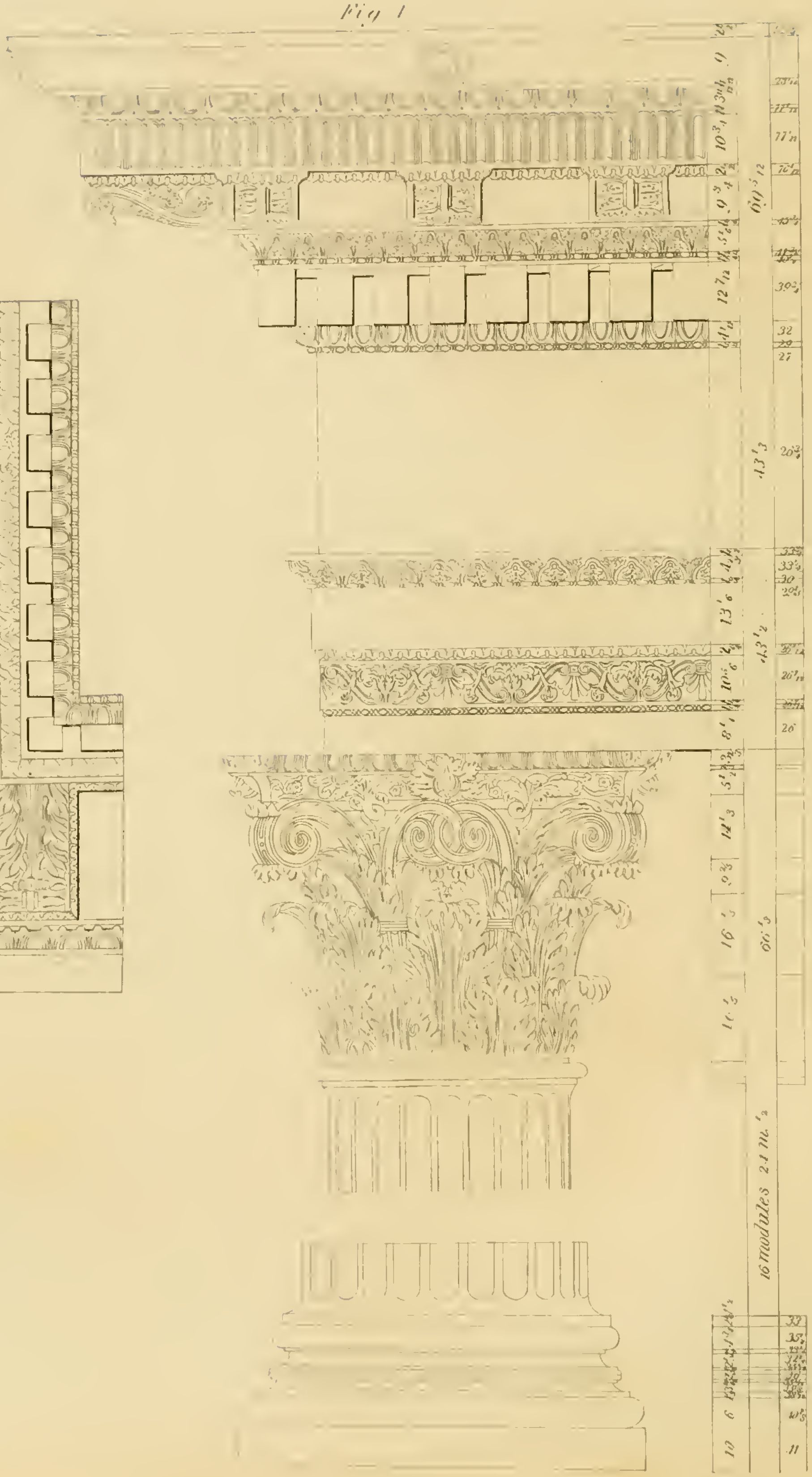
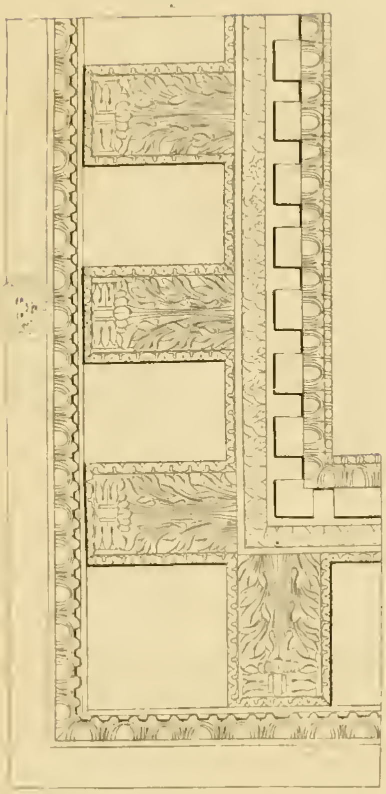


Fig. 2.



From the Pantheon and the Temple of Jupiter at Rome

Fig 1

Fig 2

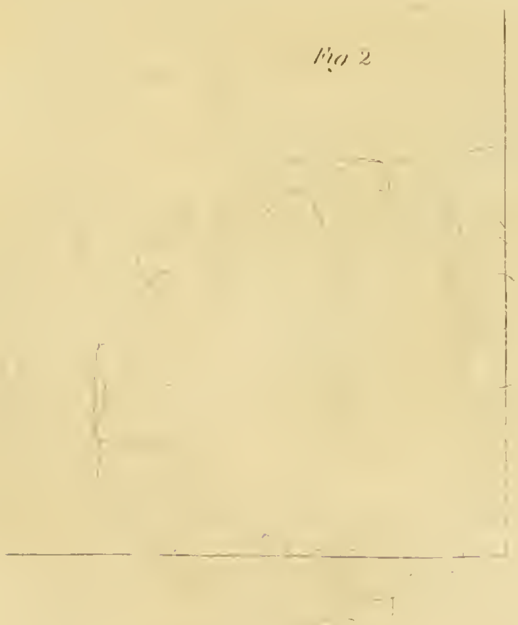


Fig 3

Fig 4

Fig 5

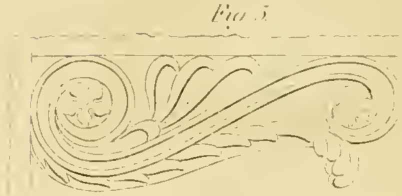


Fig 6

ROMAN CORINTHIAN.

From the Portico of the Pantheon at Rome

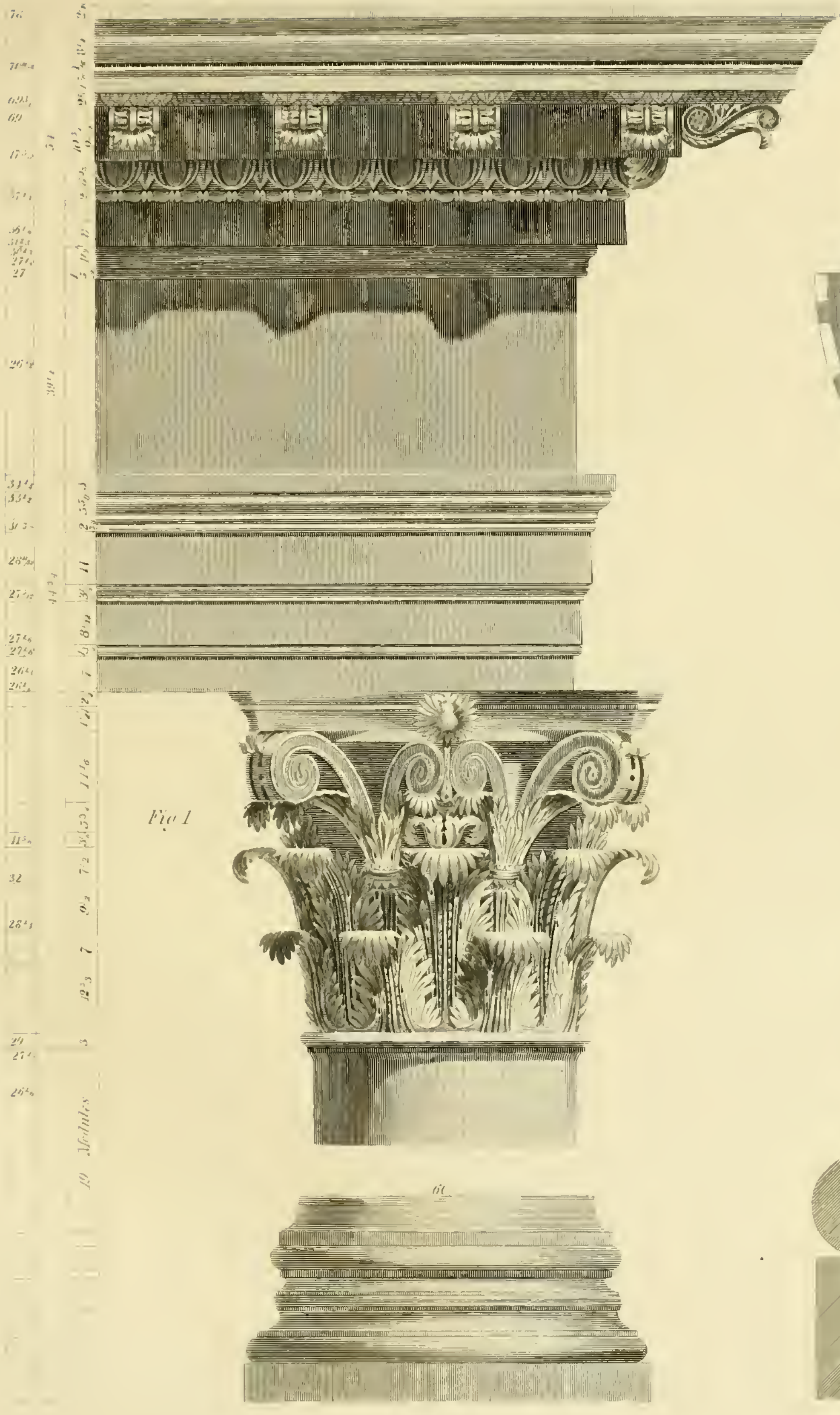
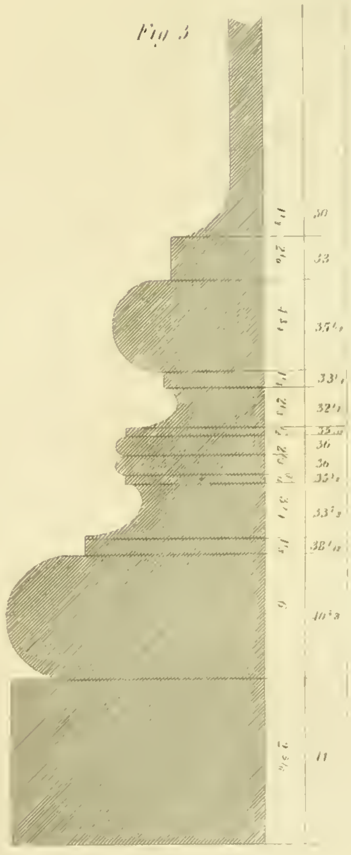


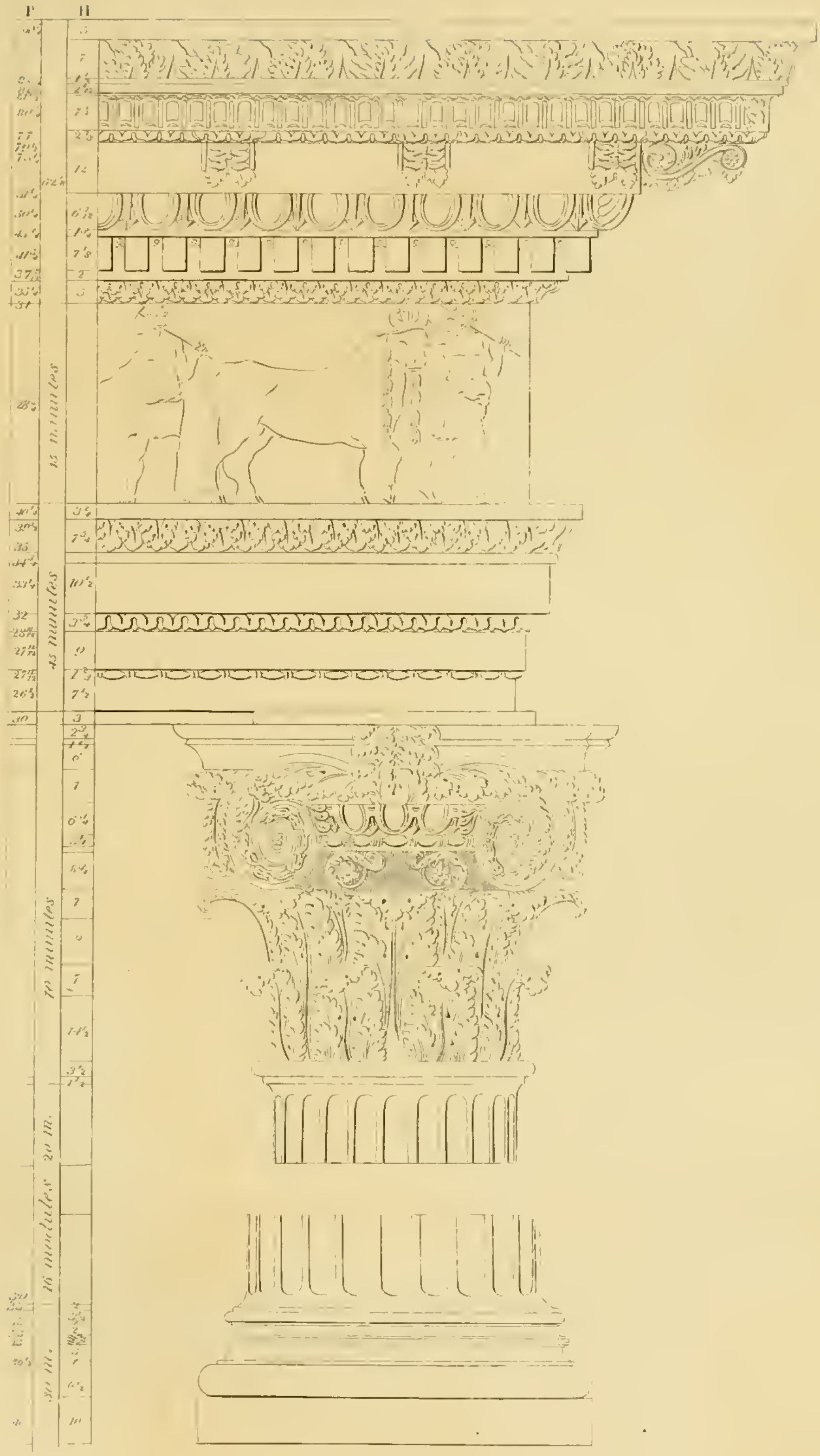
Fig 1

Fig 2

Fig 3



From the Arch of Titus at Rome



each space of the upper leaves there spring stalks with volutes, two of which meet at the angles of the abacus, and two in the middle of the capital, either touching or interwoven with each other, — a capital so constructed is called Corinthian.

2. An order which has a Corinthian capital, and an Ionic or any other entablature, is called the Corinthian order.

Plate 38.

The Corinthian Order, from the Pantheon, at Rome.

This example, though plain, is yet beautiful and chaste, and is an excellent model of the order.

Fig. 1. Elevation of the order in numbers.

Fig. 2. Section of one quarter of the column next the capital; also a section of one quarter of the column next the base.

Fig. 3. Elevation of the base of a larger size.

Plate 37.

Fig. 1. Is the outline of the leaves and elevation of the capital, from the Pantheon, as shown in plate 38.

Fig. 2. The capital inverted, showing an angle of the architrave.

Fig. 3. The elevation of a leaf in the same.

Fig. 4. The elevation of a leaf in the capital of a column, from the Temple of Jupiter Stator, at Rome.

Fig. 5. The side elevation of the modillion, from the Temple of Jupiter.

Fig. 6. The modillion inverted.

Plate 36.

From the three Columns in the Campo Vaccino, supposed to be the Remains of the Temple of Jupiter Stator, at Rome.

The engraving exhibited in this plate, of that celebrated example of the remains of Jupiter Stator, is as accurate as any yet published; the capital and entablature are restored from the drawings of an artist, who was so obliging as to favor me with sketches of the ornament which he had from the original. The elegance and beauty of the capital, its graceful form, the grandeur and excellent proportion of the entablature, with the delicacy of the ornament, render this one of the most complete examples now existing of the Corinthian order.

Fig. 1. Elevation of the order in numbers.

Fig. 2. The cornice inverted, showing the enrichments of the modillions and mouldings.

COMPOSITE ORDER.

The second Italian order, and last of the five orders of architecture, is the Composite; which some writers have divided into three species, or orders. The first, called the Composite, is composed of the Ionic and Corinthian, "which two exhibit more graces in combination than either of them would if joined with the Doric. The Composite is more slender than the Corinthian, and more ornamented with sculpture; if the latter bears any resemblance to a young maid, the former represents an harlot."

The second species, as given by Aldrich and Smyth, is "Dorico-Ionic; the only remaining instance of which may be seen at Rome, in the ruins of the Temple of Concord. The base of the column is Attico-Ionic, and without a plinth, except in angular pillars. The capital is Ionico-Doric, with the volutes projecting, as in the Italian; the abacus is Corinthian; the frieze is sculptured, but the larmier is plain. It has a beautiful appearance."

The third species of Composite is where the column is of one order, and the entablature of another; for instance, when the column is Corinthian, and the entablature Doric; in which case, it would, therefore, be very properly termed Dorico-Corinthian. "This is approved of even by Vitruvius; and, in fact, was introduced into the Temple of Solomon, whose columns were Corinthian, supporting a Doric entablature."

The Romans first introduced the Composite order into their triumphal arches, to show their dominion over the people whom they conquered.

Of this order we have many examples from the ancients; but the following is the most celebrated: it is taken from the Arch of Titus, which was executed soon after the destruction of Jerusalem, in order to commemorate that remarkable event.

Plate 39.

From the Arch of Titus, at Rome.

This most beautiful and elegant example is made choice of as the most proper model for this order.

TABLE,

Showing the relative Proportions of Grecian Doric Columns contained in this Work.

Names of Buildings.	Columus.		Capital.	Architrave.	Frieze.	Cornice.
	Modules.	Min.	Minutes.	Minutes.	Minutes.	Minutes.
Portico of Philip, K. of Macedon	13	$2\frac{1}{2}$	$4\frac{1}{6}$	38	44	25
The Temple of Theseus	11	$12\frac{1}{2}$	$30\frac{1}{2}$	50	48	32
The Temple of Minerva	11	$4\frac{1}{2}$	$27\frac{1}{2}$	$43\frac{1}{5}$	$43\frac{1}{5}$	$23\frac{3}{10}$
The Portico at Athens	12	$2\frac{1}{2}$	$21\frac{3}{4}$	40	$42\frac{1}{4}$	$21\frac{3}{10}$
Found in Asia, near the Temple of Minerva Polias			$20\frac{1}{2}$	37	35	25

PILASTERS.

Pilasters are, it is believed, a Roman invention, and certainly an improvement. The Greeks employed antæ in their temples, to receive the architraves where they entered upon the walls of the cell. These, though they were, in one direction, of equal diameter with the columns of the front, were in flank extravagantly thin in proportion to their height, and neither their bases nor capitals bore any resemblance to those of the columns they accompanied. The Roman artists, disgusted, probably, with the meagre aspect of these antæ, and the want of accord in their bases and capitals, substituted pilasters in their stead, which, being proportioned and decorated in the same manner with the columns, are certainly more seemly, and preserve the unity of the composition much better. The reader will find some additional, and perhaps not unimportant, remarks in relation to the pilaster in the introduction to this work.

Pilasters differ from columns in their plan only, which is square, while that of the column is round. Their bases, capitals, and entablatures have the same parts, with all the same heights and projections, as those of columns; and they are distinguished in the same manner, by the names of Tuscan, Doric, Ionic, Corinthian, and Composite. Of the two, the column is doubtless most perfect. Nevertheless, there are occasions in which pilasters may be employed with great propriety; and some where they are, on various accounts, even preferable to columns.

If we go back to the origin of things, and consider pilasters, either as representing the ends of partition walls, or trunks of trees reduced to the diameter of the round trunks which they accompany, but left square for greater strength, the reason for diminishing them will, in either case, be strong and evident.

It is likewise an error to assert that pilasters are never necessary, but that columns will at all times answer the same end; for, at the angles of all buildings, they are evidently necessary, both for solidity and beauty, because the angular support, having a greater weight to bear than any of the rest, ought to be so much the stronger; so that its diameter must either be increased, or its plan altered from a circle to a square. The latter of which is certainly the most reasonable expedient on several accounts, but chiefly as it obviates a very striking defect, occasioned by employing columns at the angles of a building; which is, that the angle of the entablature is left hanging in the air without any support — a sight very disagreeable in some oblique views, and in itself very unsolid.

It is indeed customary, in porches and other detached compositions, to employ columns at the angles; and it is judicious so to do, for, of two defects, the least is to be preferred.

Engaged pilasters are employed in churches, galleries, halls, and other interior decorations, to save room, for, as they seldom project beyond the solid of the walls more than fifteen minutes of their diameter, they do not occupy near so much space as engaged columns. They are likewise employed in exterior decorations; sometimes alone, instead of columns, on account of their being less expensive; at other times they accompany columns, being placed behind them to support the springing of the architraves; or on the same line with them, to fortify the angles: they may likewise be employed instead of columns, detached to form peristyles and porticoes, but there is no instance of this, that I remember, in all the remains of antiquity; neither has any modern architect, I believe, been so destitute of taste as to put it in practice.

When pilasters are used alone, as principal in the composition, they should project fifteen minutes of their diameter beyond the walls, which give them a sufficient boldness, and, in the Corinthian and Composite orders, is likewise most regular, because the stems of the volutes, and the small leaves in flank of the capital, are then cut exactly through their middles. But if the cornice of the windows should be continued in the inter-pilaster, as is sometimes usual, or if there should be a cornice to mark the separation between the principal and second story, or large imposts of arches, the projection must, in such cases, be increased, provided it is not otherwise sufficient to stop the most prominent parts of these decorations; it being very disagreeable to see several of the uppermost mouldings of an impost or cornice cut away perpendicularly, in order to make room for the pilaster, while the cornice or impost on each side projects considerably beyond it. Mutilations are, on all occasions, studiously to be avoided, as being destructive of perfection, and strong indications either of inattention or ignorance in the composer.

Where pilasters are placed behind columns, and very near them, they need not project above seven and one half minutes of their diameter, or even less, excepting there should be imposts or continued cornices in the inter-pilaster; in which case, what has been said above must be attended to. But if they

be far behind the columns, as in porticoes, porches, and peristyles, they should project ten minutes of their diameter at least; and when they are on a line with the columns, their projection is to be regulated by that of the columns; and, consequently, it can never be less than a semi-diameter, even when the columns are engaged as much as possible. This extraordinary projection, however, will occasion no very great deformity, as the largest apparent breadth of the pilaster will exceed the least only in the ratio of eleven to ten, or thereabouts. But if columns be detached, the angular pilasters should always be coupled with a column, to hide its inner flank; because the pilasters will otherwise appear disproportionate when seen from the point of view proper for the whole building, especially if the fabric be small and the point of view near.

It is sometimes customary to execute pilasters without any diminution. In the antiques there are several instances thereof, as well as of the contrary practice; and Palladio, Vignola, Inigo Jones, and many of the greatest architects have frequently done so. Nevertheless, it is certain that diminished pilasters are, on many accounts, much preferable. There is more variety in their form; their capitals are better proportioned, both in the whole and in their parts, particularly in the Composite and Corinthian orders; and the irregularities occasioned by the passage of the architraves, from diminished columns to undiminished pilasters, are thereby avoided, as are likewise the difficulties of regularly distributing the modillions and other parts of the entablature, either when the pilasters are alone or accompanied with columns.

Another disagreeable effect of undiminished pilasters is likewise obviated by rejecting them. Indeed, I am at a loss to account for it, and it is diametrically opposite to a received law in optics. I imagined it might be the result of some defect in my own sight, till, by inquiry, I found others were affected in the same manner. It is this — the top of the shaft always appears broader than the bottom.

The shafts of pilasters are sometimes adorned with flutings in the same manner as those of columns, the plan of which may be a trifle above a semicircle; and they must be to the number of seven on each face, which makes them nearly of the same size with those of the columns. The interval between them must be either one third or one fourth of the flute in breadth; and when the pilaster is placed on the pavement, or liable to be broken by the touch of passengers, the angle may be rounded off, in the form of an astragal; between which and the adjoining flute there must be a fillet or interval of the same size with the rest, as in the porch of the Pantheon, at Rome.

The flutes may, like those of columns, be filled with cablings to one third of their height, either plain, and shaped like an astragal, or enriched, according as the rest of the composition is simple or much adorned. Scamozzi is of opinion that there should be no flutings on the sides of engaged pilasters, but only in front; and, whenever cornices or imposts are continued home to the pilaster, this should be particularly attended to, that the different mouldings of these members, by entering into the cavities of the flutes, may not be cut off in irregular and disagreeable forms. But if the flanks of the pilasters are entirely free, it may be as well to enrich them in the same manner as the front, provided the flutes can be so distributed as to have a fillet or interval adjoining to the wall — which is always necessary to mark the true shape of the pilasters distinctly.

The capitals of Tuscan or Doric pilasters are profiled in the same manner as those of the respective columns; but in the capitals of the other orders, there are some trifling differences to be observed. In the antique Ionic capital, the extraordinary projection of the ovolo makes it necessary either to bend it inwards considerably towards the extremities, that it may pass behind the volutes, or instead of keeping the volutes flat in front, as they commonly are in the antique, to twist them outwards, till they give room for the passage of the ovolo. Le Clerc thinks the latter of these expedients the best; and, that the artifice may not be too striking, the projection of the ovolo may be considerably diminished, as in plate 56, Fig. 2; which, as the moulding can be seen in front only, will occasion no disagreeable effect.

The employing half or other parts of pilasters that meet, and, as it were, penetrate each other's inward or outward angles, should, as much as possible, be avoided, because it generally occasions several irregularities in the entablatures, and sometimes in the capital also. Particular care must be taken never to introduce more than one of these breaks in the same place, for more can never be necessary. In many of the churches at Rome we see half a dozen of them together, which produce a long series of undulated

capitals and bases, and a number of mutilated parts in the entablature, than which nothing can be more confused or disagreeable.

ARCADES AND ARCHES.

The arch is, without doubt, a Roman invention;* and from this circumstance the oldest, which is the semicircular, is called the Roman arch. The time of its introduction may be looked upon as a new epoch in the science of architecture, for by this change the Romans succeeded in laying the foundation for a complete revolution of taste and conception. Says Gwilt, in his Encyclopædia of Architecture, "This change, by various steps, led through the basilica to the construction of the extraordinary Gothic cathedrals of Europe, in its progress opening beauties in the art of which the Greeks had not the remotest conception." The principal feature of the Roman architecture is the use of the arch and circle, each moulding being composed of some portion; while those of the Grecian are composed entirely of sections of the cone. An arcade is a series of arches, separated by one or more columns, with their imposts and piers, and is often one of the most pleasing, as well as imposing, objects which architecture affords; and the utility of them in some climates, for shelter from rain and heat, is obvious. We have given, in plate 40, designs for arcades with and without pedestals. The proportions are very nearly the same as given by Chambers; and, as will be seen by examination, they are different in each of the orders. We should have been pleased to have given examples of arcades above arcades; but our limits would not allow it. We will state here, however, that as in orders above orders the Tuscan invariably stands at the bottom, and above it the Doric; immediately above this the Ionic, and next the Corinthian; and, should the Composite be used, its place is above the Corinthian. The lower diameter of the shaft immediately above the base of each column is of the size of the one next below it at the top just below the capital; these dimensions will, of course, govern the proportions of the entire order. If the balustrade be used in the openings, it should extend from pier to pier at the side of the column, and its whole height should be the top of the pedestal, the height of the baluster, or its dimension, is the die of the pedestal. The rails above and below them are a continuation of its cornice and base. The use of arcades above arcades is pretty generally confined to public buildings, as, among the Romans, to their theatres and amphitheatres; they have, however, been much employed in Europe; and in the magnificent design made by Inigo Jones, for the palace at Whitehall, are to be found some very fine examples. — EDITORS.

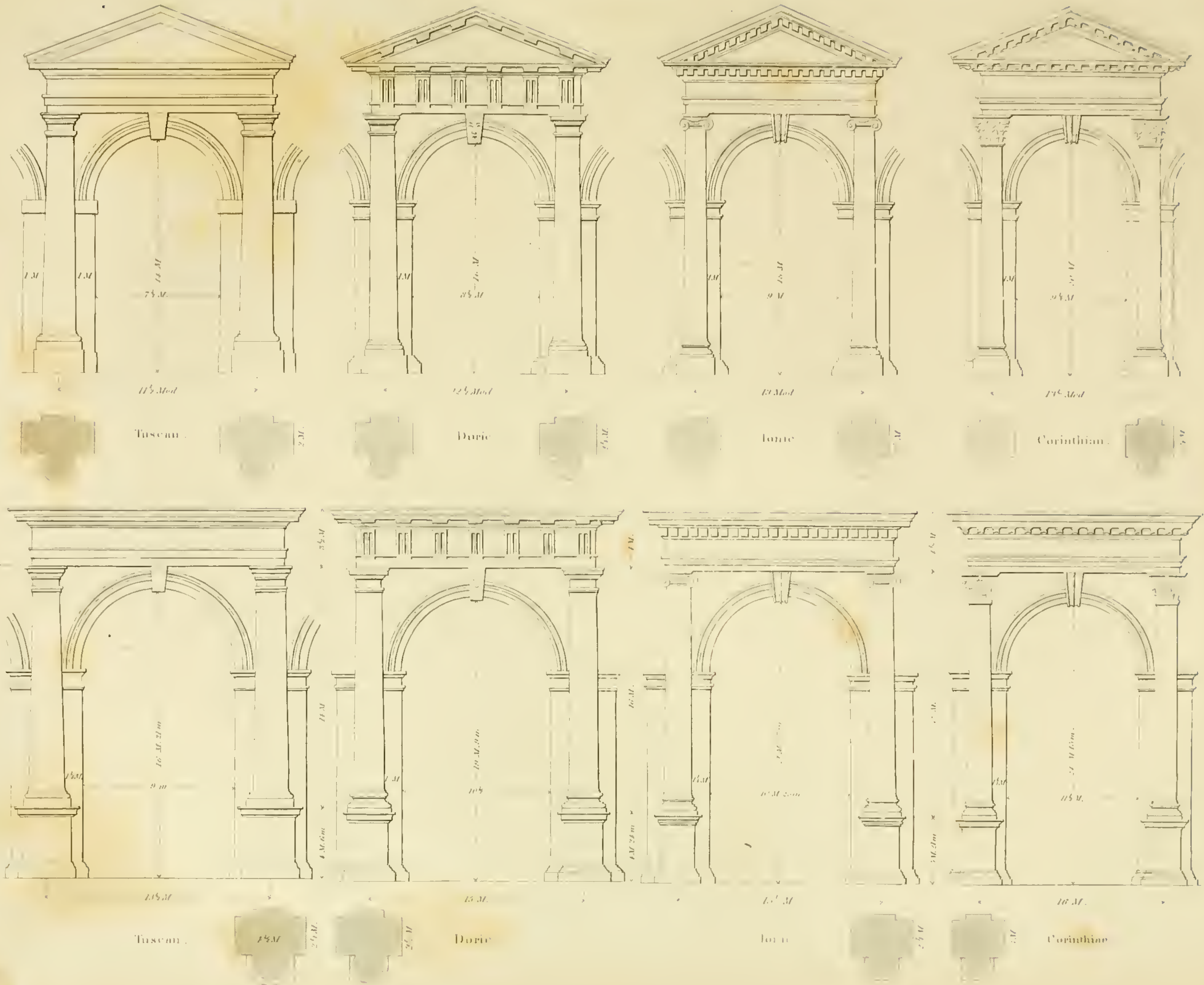
* We are aware that, were we to pass over this point without alluding to the discovery of an arch at Thebes, we should not feel warranted in making the above assertion. An account of this arch may be found in Wilkinson's Customs of the Ancient Egyptians, vol. iii. pp. 221 and 263. To the arch of Thebes Mr. W. assigns the date of 1500 B. C. But as this structure, if one may judge from his delineation, is so purely Roman in its character, its antiquity is doubted by most authors. The arch in the tomb of Saccara is the other to which he alluded, and is from his delineation simply a lining, and is not capable of sustaining any weight, which is the office of the arch. Mr. Wilkinson assigns as a reason for the Egyptians not using the mode of construction requiring the arch, that there would be difficulty attending the repairing of any accident that might befall it. In regard to this argument, it would seem, at any rate, that, to an engineer who could erect the Pyramid of Cheops, some way would suggest itself for the repairs of a simple arch, had he ever conceived of its construction. He again speaks of the consequences attending the decay of a single block, &c. In regard to this it is argued, that, in the case alluded to, the balance on the outer side or back of each course would preserve the opening in some form without any arch at all. And besides this, when we take into consideration the fact that so much time and labor was expended to procure the immense stones for architraves, which could have been avoided in many instances by the use of the arch, it seems that, had it existed in their very midst, some, to say the least, would have ventured to use it. — EDITORS.

PEDESTALS.

Most writers consider the pedestal as a necessary part of the order, without which it is not esteemed complete. It is, indeed, a matter of small importance whether it be considered in that light or as a distinct composition. Vitruvius only mentions it as a necessary part in the construction of a temple, without signifying that it belongs to the order, or assigning any particular proportions for it, as he does for the parts of the column and the entablature. But triangular, circular, or polygonal pedestals, or such as are swelled and have their die in the form of a baluster, or are surrounded with cinctures, are, in no case, to be made use of in buildings. Such extravagances, though frequent in some foreign countries, are now laid aside wherever good taste prevails.

A pedestal, like a column or an entablature, is composed of three principal parts, which are the base, the body or the die, and the cornice. The die is always

Pl. 10



Tuscan.
Doric
Ionic
Corinthian.
Tuscan.
Doric
Ionic
Corinthian

nearly of the same figure, being constantly either a cube or a parallelopiped; but the base and cornice are varied, and adorned with more or less mouldings, according to the simplicity or richness of the composition in which the pedestal is employed. Hence pedestals are, like columns, distinguished by the names of Tuscan, Doric, Ionic, Corinthian, and Composite.

Some authors are very averse to pedestals, and compare a column raised on a pedestal to a man mounted on stilts, imagining that they were first introduced merely through necessity and for want of columns of a sufficient length.

It does not seem proper to suppose that they were first introduced merely through want of columns of a sufficient length, since there are many occasions on which they are evidently necessary, and some in which the order, were it not so raised, would lose much of its beautiful appearance. Thus, within our churches, if the columns supporting the vault were placed immediately on the ground, the seats would hide their bases and a good part of the shafts; and in the theatres of the ancients, if the columns of the scene had been placed immediately on the stage, the actors would have hid a considerable part of them from the audience; for which reason it was usual to raise them on very high pedestals, as was likewise customary in their triumphal arches; and in most of their temples the columns were placed on a basement or continued pedestal, so that the whole order might be exposed to view, notwithstanding the crowds of people with which these places were frequently surrounded. And the same reason will authorize the same practice in our churches, theatres, courts of justice, and other public buildings where crowds frequently assemble. And in a second order of arcades there is no avoiding pedestals, as without them it is impossible to give the arches any tolerable proportion. These instances will sufficiently show the necessity of admitting pedestals in decorations of architecture. With regard to the proportion which their height ought to bear to that of the columns they are to support, it is by no means fixed — the ancients and moderns, too, having in their own works varied greatly in this respect, and adapted their proportions to the occasion, or to the respective purposes for which the pedestals were intended. Thus, in the amphitheatres of the ancients, the pedestals in the superior orders were generally low, because in the apertures of the arches they served as rails to enclose the portico, and therefore were, for the conveniency of leaning over, made no higher than was necessary to prevent accidents; and the case is the same in most of our modern houses, where the height of the pedestals in the superior orders is generally determined by the sills of the windows. The ancients, in their theatres, made the pedestals in the first order of their scene high, for the reason mentioned in the beginning of this chapter; but the pedestals in the superior orders were very low, their chief use being to raise the columns so as to prevent any part of them from being hid by the projection of the cornice below them; and thus, on different occasions, they used different proportions, being chiefly guided by necessity in their choice.

Nevertheless, writers on architecture have always thought it incumbent upon them to fix a certain determinate proportion for the pedestal, as well as for the parts of the order. It would be useless to enumerate in this place their different opinions; but I must beg leave to observe that Vignola's method is the only true one. His pedestals are all in the orders of the same height, being one third of the column; and as their bulk increases or diminishes, of course in the same degree as the diameters of their respective columns do, the character of the order is always preserved, which, according to any other method, is impossible.

With regard to the divisions of the pedestals, if the whole height be divided into nine parts, one of them may be given to the height of the cornice, two to the base, and the remaining six to the die; or if the pedestal is lower than ordinary, its height may be divided into eight parts only, of which one may be given to the cornice, two to the base, and five to the die, as Palladio has done in his Corinthian order, and Perault in all the orders.*

The plan of the die is always made equal to that of the plinth of the column; the projection of the cornice may be equal to its height; and the base, being divided into three parts, two of them will be for the height of the plinth, and one for the mouldings, of which the projection must be somewhat less than the projection of the cornice, so that the whole base may be covered and sheltered by it.

These measures are common to all pedestals; and in plate 41 there are proper designs for the Tuscan,

* Ordonnance des cinq Especes de Colonnes, 1 Partie, ch. 6 et 7.

Doric, Ionic, and Corinthian orders, in which the forms and dimensions of the minuter parts are accurately drawn and figured. With regard to the application of pedestals, it must be observed that when columns are entirely detached, and at a considerable distance from the wall, as when they are employed to form porches, peristyles, or porticoes, they should never be placed on detached pedestals, for then they may indeed be compared to men mounted on stilts, as they have a very weak and tottering appearance.

The base and cornice of these pedestals must run in a straight line on the outside throughout; but the dies are made no broader than the plinths of the columns, the intervals between them being filled with balusters, which is both really and apparently lighter than if the whole pedestal were a continued solid.

TABLE,

Showing the Height of Pedestals in antique and modern Works in Minutes, each one sixtieth of the Diameter of the Shaft.

		Plinth.	Mouldings above Plinth.	Die.	Cornice.	Total Height.
		Min.	Min.	Min.	Min.	Min.
Doric, ...	Palladio,................	26	14	80	20	140
	Scamozzi, ...	30	15	$68\frac{4}{7}$	$22\frac{1}{2}$	$136\frac{1}{14}$
Ionic, ...	Temple of Fortuna Virilis,	44	$19\frac{3}{4}$	$93\frac{3}{4}$	$23\frac{1}{4}$	$180\frac{3}{4}$
	Coliseum, ...	$33\frac{1}{4}$	$9\frac{1}{2}$	$81\frac{5}{6}$	17	$141\frac{1}{2}$
	Palladio, ...	$28\frac{2}{3}$	$14\frac{1}{3}$	$97\frac{3}{4}$	$21\frac{1}{2}$	$162\frac{1}{4}$
	Scamozzi, ...	30	15	$82\frac{1}{2}$	$22\frac{1}{2}$	150
Corinthian,	Arch of Constantine, ...	$17\frac{1}{2}$	29	153	$29\frac{1}{2}$	228
	Coliseum, ...	23	$11\frac{1}{2}$	78	$19\frac{1}{4}$	$131\frac{3}{4}$
	Palladio,.................	$23\frac{1}{2}$	$14\frac{1}{2}$	93	19	150
	Scamozzi, ...	30	15	$132\frac{1}{2}$	$22\frac{1}{2}$	200
Composite,	Arch of Titus,...........	55	30	141	29	255
	Arch of the Goldsmiths,.	46	$25\frac{1}{4}$	$144\frac{1}{2}$	$25\frac{1}{4}$	241
	Palladio, ...	33	17	133	17	200
	Scamozzi,...............	30	15	$112\frac{1}{2}$	$22\frac{1}{2}$	180
	Arch of Sep. Severus, ...	30	$30\frac{5}{6}$	$140\frac{1}{2}$	$29\frac{5}{6}$	$182\frac{1}{6}$

On plate 41 will be found designs for pedestals of the different orders. They are figured by the same scale with which the order should be drawn in which they may be employed.

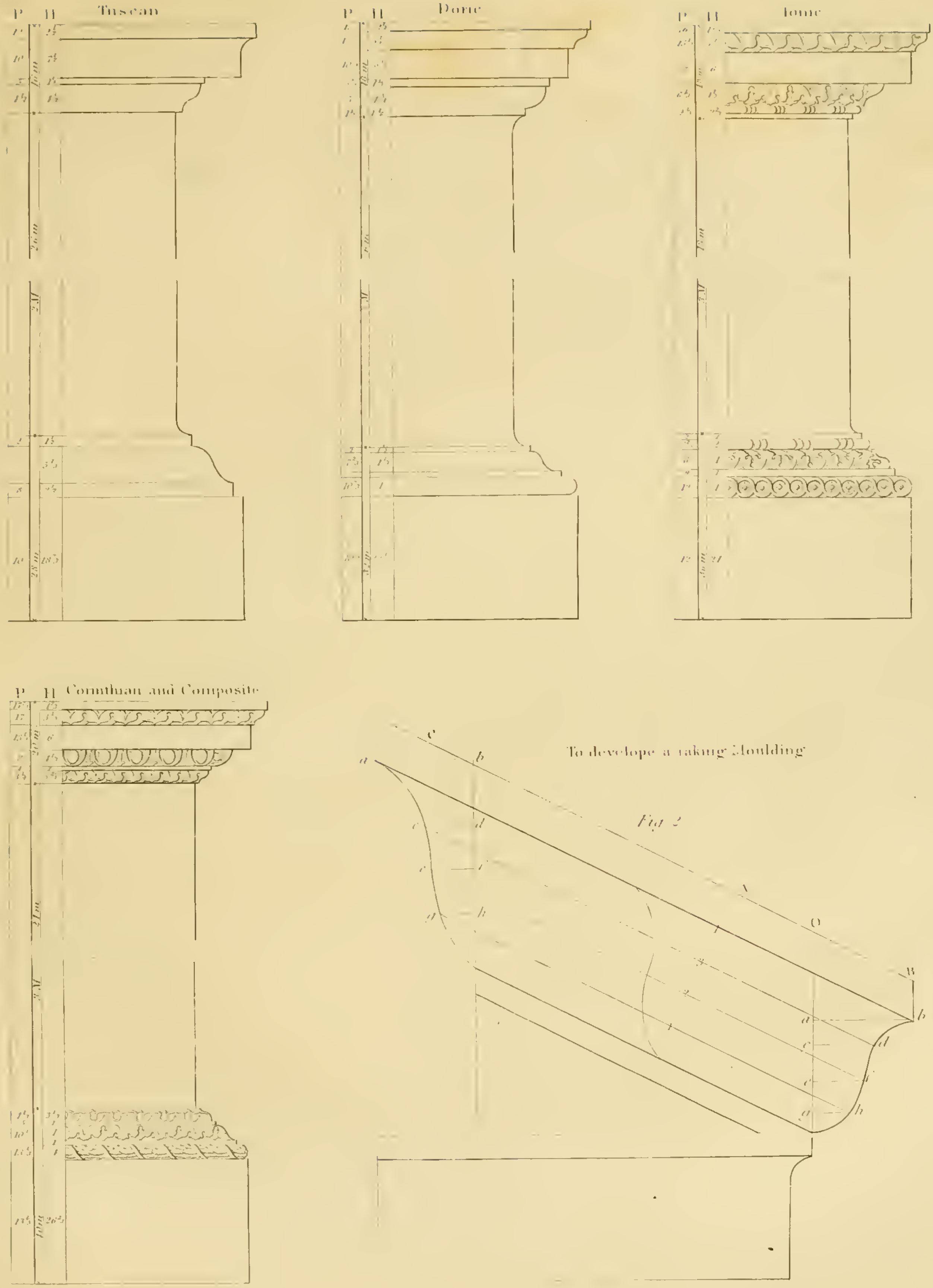
Fig. 2. In this figure is shown the manner of striking or working a raking moulding to fit and mitre with the same on a horizontal line or flank. First divide the width of the moulding into 1, 2, 3, and 4 parts, as in A; raise a perpendicular line in B, at O; trace the curve of the moulding from the intersection of 1, 2, 3, 4, on the curve line of the moulding; draw *a*, *b*, *c*, *d*, *e*, *f*, *g*, *h*, at right angles with the perpendicular line O, to the points *h*, *f*, *d*, *b*, in the curve or face of the moulding; transfer to A, *a b*, *c d*, *e f*, *g h*. In the like manner, the curve at C may be found. All to mitre in their several parts with each other.

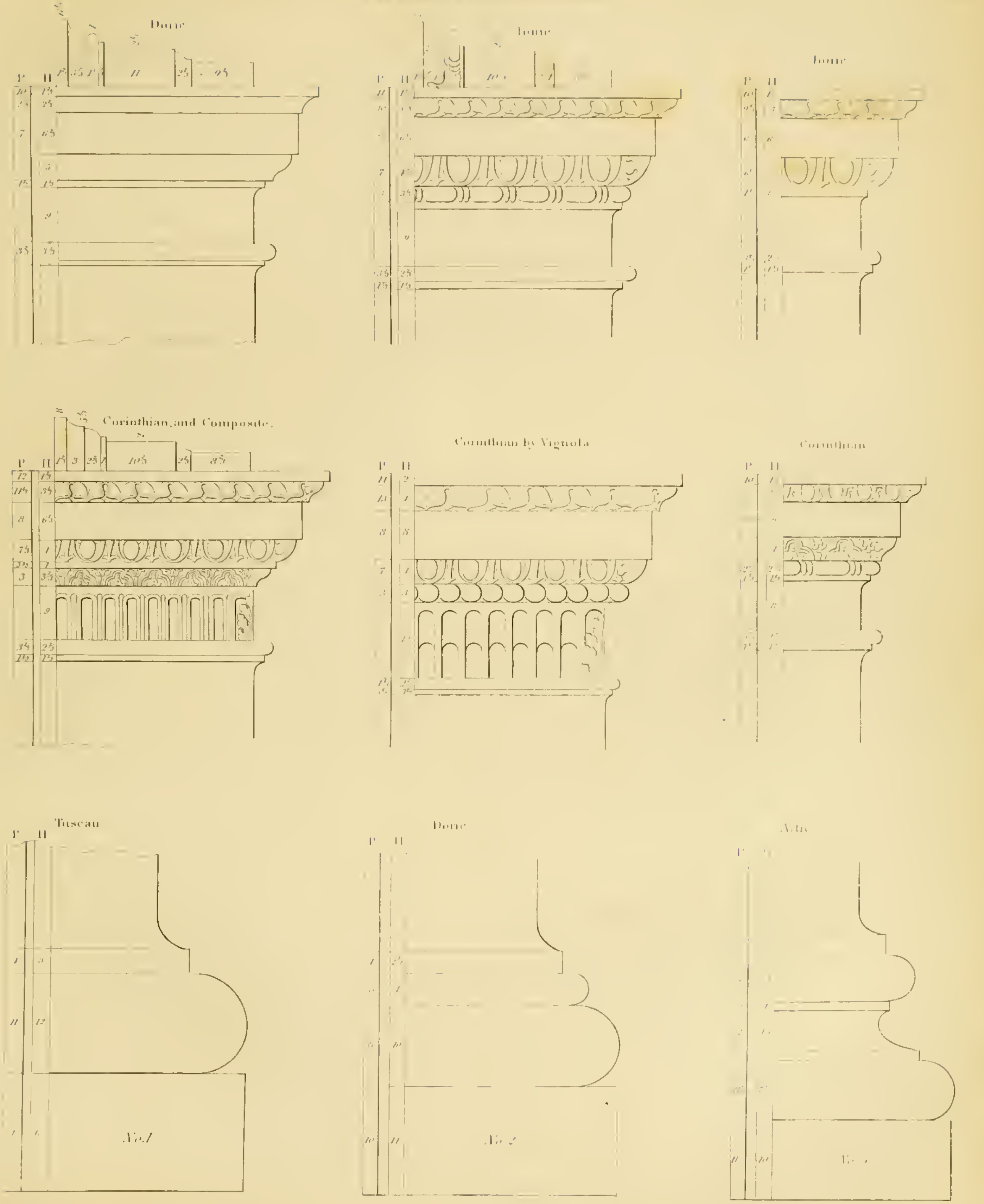
IMPOSTS.

Imposts are explained in the glossary. By some, however, they are called the walls back of the inserted column, rising from the base to the spring line of the arch, and extending on each side of the column about thirty minutes — forming the side of the apertures of doors or windows, and, when used without the columns, are appropriately termed pilasters. But they are most generally used for those assemblages of moulding which divide the perpendicular part of the wall from the spring line of the arch. In some instances regular pilasters are introduced, when the column may be termed isolated, as it stands detached from the walls. We find imposts introduced in the Temple of Solomon; and they are common in Roman edifices; as in the Arch of Titus, and most of their other triumphant arches, &c. In most parts of Europe imposts are found, as also in some parts of the United States. The origin of this style of building cannot be clearly traced. However elegant its aspect in many instances may be, it seems now to be giving place to a more magnificent and majestic style of architecture. Where we once saw one range of columns rising above another, each supporting a distinct entablature, we now find the whole height supplied by one length, thus preserving the principles of good taste.

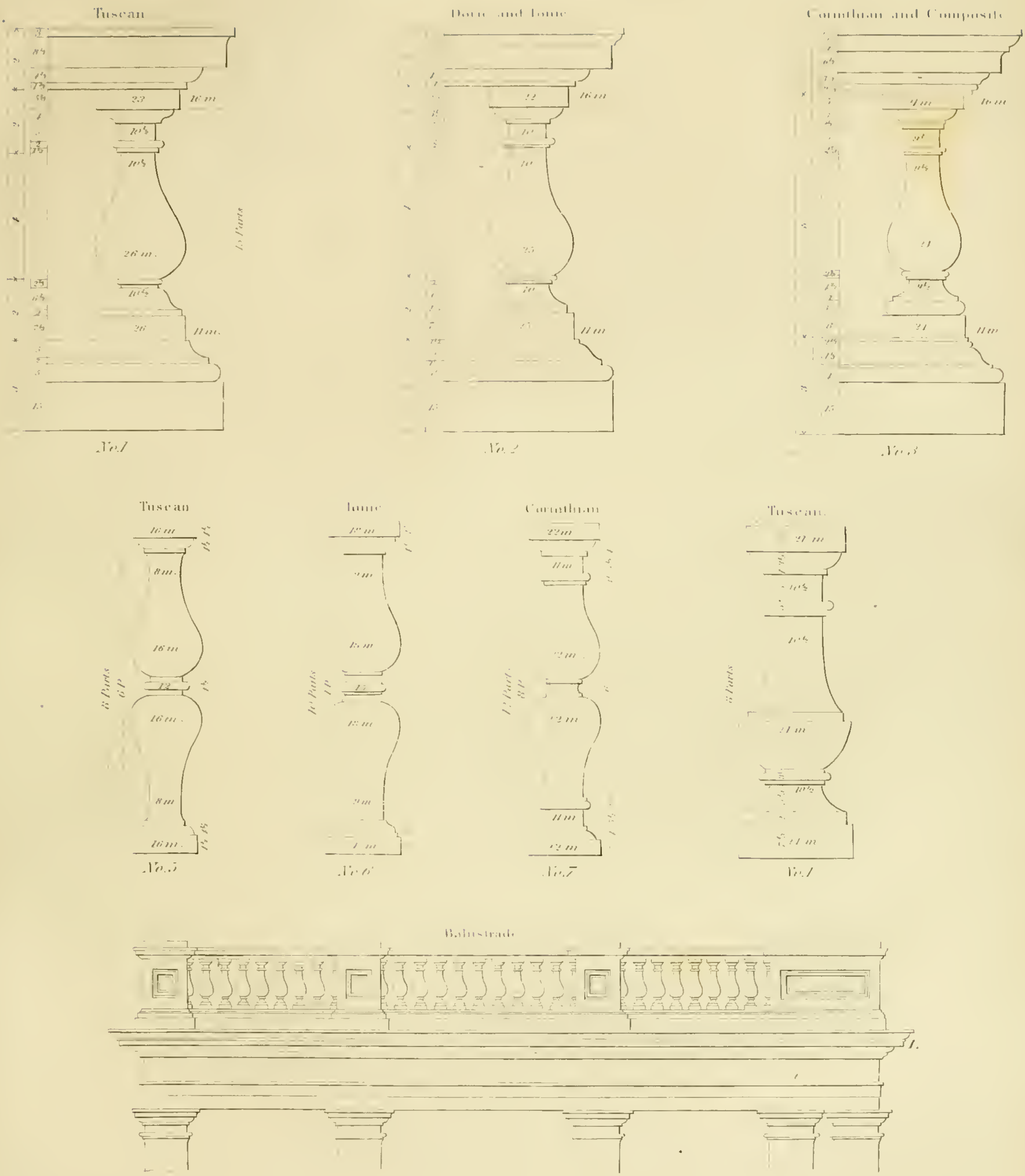
An *impost* is the capital of a pier or pilaster which receives the arch in the arcades of the Roman order. On plate 42 we have given designs for the different orders, and have figured them to be drawn by the same scale of minutes with which the order is drawn to which they may be applied. No. 4 is from a design by Vignola; the rest are by Sir William Chambers.

Bases. — No. 1 is the Tuscan base; No. 2 is the Doric; and No. 3 is the Attic. The last named Chambers has used with all his orders, excepting the Tuscan. This base was used by the ancients to a great extent; and they have not, to say the least, in many instances made any improvement — Editors.


Tuscan
Doric
Ionic
Corinthian and Composite
To develope a raking Moulding
Fig 2



Doric
Ionic
Ionic
Corinthian, and Composite.
Corinthian by Vignola
Corinthian
Tuscan
Doric
Attic
No. 1
No. 2


Tuscan
Doric and Ionic
Corinthian and Composite
No.1
No.2
No.3
Tuscan
Ionic
Corinthian
Tuscan
No.5
No.6
No.7
Balustrade

BALUSTRADES.

The baluster is not found in the works of the ancients, but owes its origin to the restoration of the art in Italy. It, like the column, consists of the capital, shaft, and base. The most ancient examples were of the shape of a stunted column, and not unfrequently were crowned with a disproportioned Ionic capital. Many forms have been given to them by the later masters, and we may safely say that the invention is one of the most useful as well as ornamental that was produced by the Italians. A balustrade is a series of balusters standing upon a base, and crowned with a capital or rail, — this capital and base being of the same outline in its detail as those of the pedestal which accompany them. It is proposed by Blondel that balusters and balustrades should partake of the character of the edifice they are to be employed upon; and by some their species has been so arranged as to appropriate a design to each order, and in the works of such they are known by the name of Tuscan, &c. The general rules to be observed in the construction of balustrades are, that the balusters be of an odd number, and the distance between them equal to half their larger diameter, which will produce an equality between the open and solid spaces; and a half baluster should always be placed against the pedestal. When the balustrade is formed without pedestals, as is often the case where balusters are placed between columns, the half baluster may be omitted. The pedestals of balustrades should always be placed directly over the column, and the die be of the same width as the diameter of the column at the top. Where the columns stand together as in what is termed coupled columns, as seen at A, in plate 43, the pedestal should extend over both entire. Also, where a balustrade terminates against a roof or pediment, the termination should be by a pedestal, and it should commence where the balustrade begins to diminish, be the distance more or less; and in no case should the baluster be cut to the roof. The pedestals, as before stated, should stand directly over the columns, — the distances between them would, of course, depend upon the intercolumniation, — but where no columns are used, either seven or nine whole balusters, with the half ones, have been recommended as producing the best effect; for when the pedestals stand too near each other, they present a heavy and clumsy appearance to the work; and where they are too far apart, the work will appear weak. The bulbs or bellies of balusters are often enriched; which, for stairs and highly-finished interiors, is quite requisite. In regard to the heights of balustrades, when they are used as a protection to terraces, or before windows, they should be not less than two feet six inches, nor more than three feet high; but when they are used as merely ornamental appendages to a building, they should be, according to the majority of authors, not more than two thirds of the height of the entablature over which they stand, nor less than two thirds, without counting the plinth, the height of which must be sufficient to leave the entire baluster exposed to view from the best point of sight for viewing the building. Palladio has, however, in some instances, made the balustrade the height of the entire entablature, as at the Valmarana Palace. Inigo Jones has, in some instances, followed his example; but this was not the usual practice of either. We have before stated, that the moderns have given to the baluster a variety of shapes. On plate 43 we have given the designs recommended by Chambers, with the method of proportioning them, in the manner adopted by him. No. 1 is the Tuscan; No. 2 the Doric and Ionic; No. 3 the Corinthian and Composite. No. 4 is a design for a Tuscan baluster, and has generally been executed square. Nos. 5, 6, and 7 are designs for double-bellied balusters, and are intended principally for balconies and terraces, the rail and pedestal being the same height as in other designs. Chambers has designated them respectively the Tuscan, Doric, and Ionic and Corinthian. The method of proportioning them to the order is as follows: After ascertaining the height, as before directed, divide it into thirteen parts; of which, give two to the rail, eight to the baluster, and the remaining three to the base: if the baluster is required to be less, divide the height into fourteen parts, giving two to the rail, eight to the baluster, and four to the base. One of these parts is a module for determining the rest, and is divided into nine other parts, called minutes. From what has been said, the whole on plate 43 will, without doubt, be clearly understood. — Editors.

GRECIAN ORDERS.

The Doric, the Ionic, and the Corinthian were the only orders of architecture employed by the Greeks. The Tuscan and Composite were used only in Italy — the one more rude, the other more ornamented, than the Greek orders, which occupied a middle rank. To attain, therefore, a proper knowledge of the true principles of architecture, the student should devote most of his attention to the three Greek orders; not only because in them these principles are the most displayed, but because of all the monuments of antiquity which have subsisted to modern times few, or perhaps none, can be pointed out in which the Roman or Italic mode of construction is certainly to be traced.

DEFINITIONS.

1. If any number of frustums of cones, or frustums of conoids of similar solids and equal magnitudes with each other, be so arranged that their bases, which are the thickest ends of the frustums, may stand upon or in the same horizontal plane, and their axes in the same plane with each other and perpendicular to the horizon; and if on the tops of these frustums be laid a continued beam; and if over this beam be laid the ends of a number of equidistant joists, the other ends being either supported in the same manner, or by a wall or any piece of building whatever, so that the upper and under surfaces may be in the same horizontal planes; and if over the ends of these beams be laid another beam parallel to the former, which lays upon the frustums, but projecting farther out from the axis of the columns than the vertical face of the lower beam which is over the frustums; and if this beam supports the ends of rafters whose upper surfaces lay in the same inclined plane, so as to support a covering or roof, — the whole of this mass, together with the frustums supporting it, is called an *order*.

2. If the bottom or lower end of the frustum finish with an assemblage of mouldings, projecting equally all round beyond the bottom of the frustum, then this assemblage is called a *base*.

3. If the upper end of the frustum finish with mouldings or any kind of ornaments, and if these ornaments or mouldings be covered with a solid, whose upper end and lower sides are square, and the vertical or perpendicular sides rectangles, then this solid, together with the ornaments or mouldings under it, is called a *capital*.

4. If the frustum has no base, then the capital and frustum together are called a *frustum column;* but if the frustum has a base, then the base, frustum, and capital, taken together, are simply called a *column*.

5. The mass supported by the columns is called an *entablature*.

6. The under beam of the entablature is called an *architrave* or *epistylium*.

7. The space comprehended between the upper side of the epistylium or architrave and the under edge of the beam over the joists, is called the *frieze* or *zophorus*.

8. The edge or profile of the inclined roof supported by the joists or cross beams, jetting out beyond the face of the zophorus or frieze, is called a *cornice*.

9. The lowest or thickest part of a column is called the *diameter of the column*.

10. Half of the diameter of the column is called a *module*.

11. If a module be divided into thirty, or any other number of equal parts, then these parts are called *minutes*.

12. The shortest distance from the bottom of the frustum of one column to the bottom of the frustum of the next column is called the *intercolumniation*.

13. When the intercolumniation is one diameter and half a column, it is called *pycnostyle*, or *columns thick set*.

14. When the intercolumniation has two diameters of the columns, then it is called *systyle*.

15. When the space between the columns is two diameters and a quarter, then the intercolumniation is called *eustyle*.

16. When the intercolumniation is three diameters of the columns, then it is called *decastyle*.

17. When the distance between the columns has four diameters of the columns, then that intercolumniation is called *aræostyle*, or *columns thin set*.

18. When there are four columns in one row, then that number is called *tetrastyle*.

19. When there are six columns in one row, then it is called *hexastyle*.

20. When there are eight columns in one row, then it is called *octastyle*.

GRECIAN DORIC.

The first Grecian order in point of antiquity is the Doric, so called from the Dores, a small tribe in Greece; or, as some say, from Dorus, an Achaian chief, who first employed the order in erecting a temple to Juno, at Argos.

DEFINITIONS.

1. If through the axis of the shaft be supposed to pass twenty vertical planes, making equal angles with each other, which will cut the surface of the column in twenty places; and if the surface of the column be curved or hollowed between each two lines, from the bottom to the top of the shaft, terminating immediately under the lowest annulet, — then the shaft will have twenty curved sides, and as many angles; and if nearly at the upper end of the shaft be cut one or more grooves, of an equal depth from the surface of the hollowing, each groove being parallel to the annulets under the echinus, then a column so formed is called *Doric*.

2. That part of the column contained between the upper channel and the lower annulets is called the *hypotrachelion*, *neck*, or *frieze of the capital*.

3. That part of the Doric column comprehending the abacus, echinus, annulets, and hypotrachelion, is called a *Doric capital*.

4. If the ends of the cross beams in the frieze which lay upon the architrave be at right angles to the sides of the beams, and parallel to the front or the architrave; and if the two vertical right angles of each beam formed by the two vertical sides and the ends be cut away by vertical planes, making equal angles with the sides and ends, — that is, 135 degrees with each, — and if two other vertical channels are cut on the end, so that the planes, which are three in number, left on the ends of each beam, may be equal rectangles, and the two sides of each channel make 135 degrees with the ends of the joists, and are so disposed that there may be a rectangle next to each semi-channel, and then two whole channels, leaving a rectangle in the middle, — the end of the beam so formed is called a *triglyph*.

5. If the spaces between the triglyph be filled up with planes parallel to the front of the triglyphs or to the front of the architrave; and if these planes be in the same plane with each other and recessed beyond the ends of the triglypn, so as to show a small part of the vertical sides of the beams, — that is, to be farther in than the channels of the triglyph, — then these spaces so filled up are called *metopes*.

6. If the front of the beam which supports the rafters that lay upon the joists projects at some distance beyond the face of the triglyph, the plane of the front being parallel to the ends of the beam; and if a recess be cut from this beam directly over the metopes, the plane of the front of the recess being parallel to, and having a small projecture over, the metopes, and the ends of the recesses over the metopes be in the same plane with the vertical sides of the beam, — then that part of the front of the beam over the triglyph is called the *capital of the triglyph*.

7. The whole face of the work comprehended between the upper edge of the beam which forms the capital of the triglyphs, and the lower end of the triglyphs and metopes, is called a *Doric frieze*.

8. If from the top of the architrave project a fillet whose upper edge is in the same plane with the top of the architrave or the lower end of the triglyph, the front of the fillet being a vertical plane parallel to the front of the architrave, having a small projecture beyond the front of the triglyph, this fillet being supposed to be continued the whole length of the architrave, and returning in the same manner round its ends; and if fillets be placed under this fillet, whose fronts stand a little within the front of the upper fillet, but projecting beyond the face of the architrave and the ends of these fillets, in the same plane with the sides of the triglyph, and, consequently, each fillet equal in length to the breadth of the triglyph; and if under each of these fillets be fixed six equal similar frustums of cones, at equal distances from each other, whose axes are perpendicular to the horizon, and the same distance from the face of the architrave, so that the extremities of these frustums may not reach beyond the perpendicular of the ends of the fillets above them, — then the front of the architrave so formed is called a *Doric architrave*.

9. The upper fillet of the Doric architrave is called a *tenia*.

10. The fillets under the tenia of the Doric architrave are each of them called a *regula*.

11. The little conical frustums under each regula are called *guttæ*, or *drops*.

12. The plain part of the architrave under the tenia and regulæ is called *facia.*

13. If over the capitals of the triglyph be laid another beam, whose front is parallel to the metopes or to the front of the triglyphs in the frieze, having a small projecture from the front of the metopes; and if over this beam be laid the ends of the rafters which support the covering, the ends having a projecture forward and parallel to the beam under them, one rafter over each triglyph, and also one over every metope, placed directly in the middle of each; that is to say, a vertical plane perpendicular through the middle of every metope, and also through the middle of every triglyph, would pass through the ends of all the rafters, and divide them into two equal rectangles; and if over the rafters be laid a beam, the front of which, being a plane parallel to the ends of the rafters, has a projecture; and if the void spaces between each two rafters and the under side of the beam above the rafters and the upper side of the beam below the rafters be covered in, so that the front of the spaces so covered may be in the same vertical plane with the face of the beam under the rafters, — then those ends of the rafters projecting over the face of the beam under them are called *mutules.*

14. If to the under side of the mutules be hung three rows of small conical frustums, of the same size as those under the regulæ of the architrave, so that there may be six in length in each of the rows, and three in width, then these conical frustums are also called *guttæ*, or *drops*, as those in the architrave.

15. The front of the beam lying over the mutules is called *corona*, or *drip*, or *larmier.*

16. The under side of the beam lying over the mutules is called *soffit*, or *lacunar.*

17. A building, whether of wood or stone, or any other material, having columns supporting an entablature over them, as described in the preceding definitions, — such a building, so constructed, is said to be of the *Doric order.*

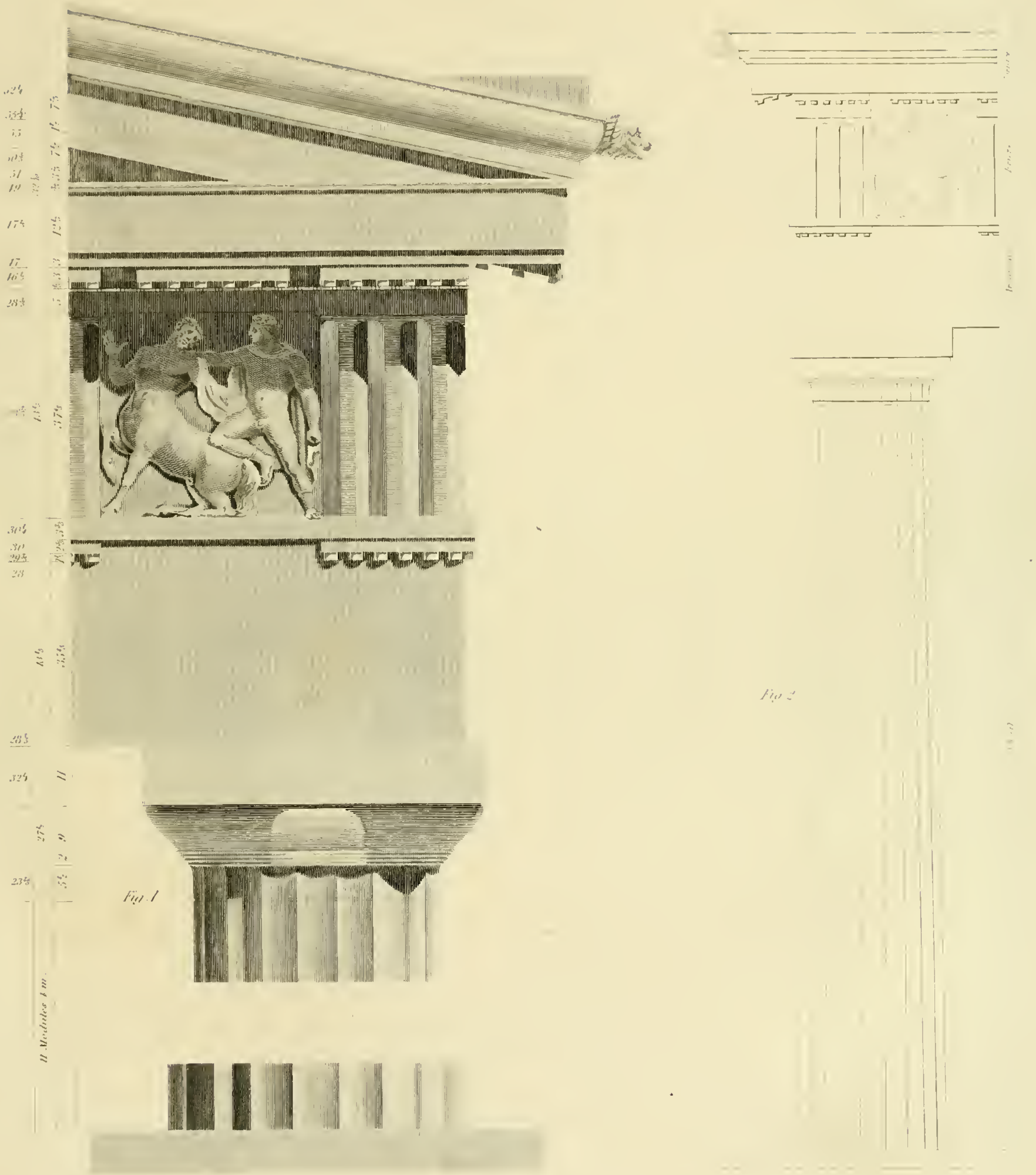
Having defined the principal parts of this order, it may not be improper to observe that the Doric order has, in general, more mouldings in the cornice; but as these vary in different buildings, and as the members already described form its most striking features, i would have been useless to have taken any account of them in the definitions.

PROBLEM 1

To draw the elevation of a Grecian Doric order.

Make the lower diameter of the shaft of the column one eighth of the entire height of the order; divide the diameter of the column into two equal parts; then one of these parts is a module; divide the module into thirty equal parts, and each of these parts will be a minute; make the height of the column twelve modules, the height of the capital one module; divide the height of the capital into five equal parts; give one to the hypotrachelion, and two parts to the annulets and echinus; make the annulets one quarter of the echinus, and the remaining two parts to the abacus; make the upper diameter of the shaft three quarters of the lower diameter of the shaft, the length of each side of the abacus two modules and one fifth, or two modules and twelve minutes; the height of the entablature will be four modules, of which the height of the cornice will have one module, and the frieze and architrave each forty-five minutes, or one module and a half; divide the height of the frieze into eight parts; give the upper one to the capital of the triglyph, and the three lower for the channels; make one edge of the triglyph in the columns at the angles of the building, directly over the axis of the column, the breadth of the triglyph twenty-eight minutes, having the other edge of the triglyph directly at the angle of the building; and make the distance between the triglyph, or width of the metopes, equal to the height of the frieze, forty-two minutes; place all the columns between the two extreme ones directly under the middle of the triglyphs. Make the height of the tenia one tenth of the height of the epistilium; and the height of the regula, together with the guttæ, equal to the height of the tenia. The height of the cornice being one module, make the height of the small bead on the lower part of the cornice one minute; the height of the mutules, including the guttæ, four minutes and a half; the length of the mutules equal to the breadth of the triglyphs, and their projection beyond the faces of the triglyphs two thirds of their length, observing that one should be directly over the middle of every triglyph, and one over the middle of every metope; make a fillet above the mutules

From the Temple of Minerva at Athens



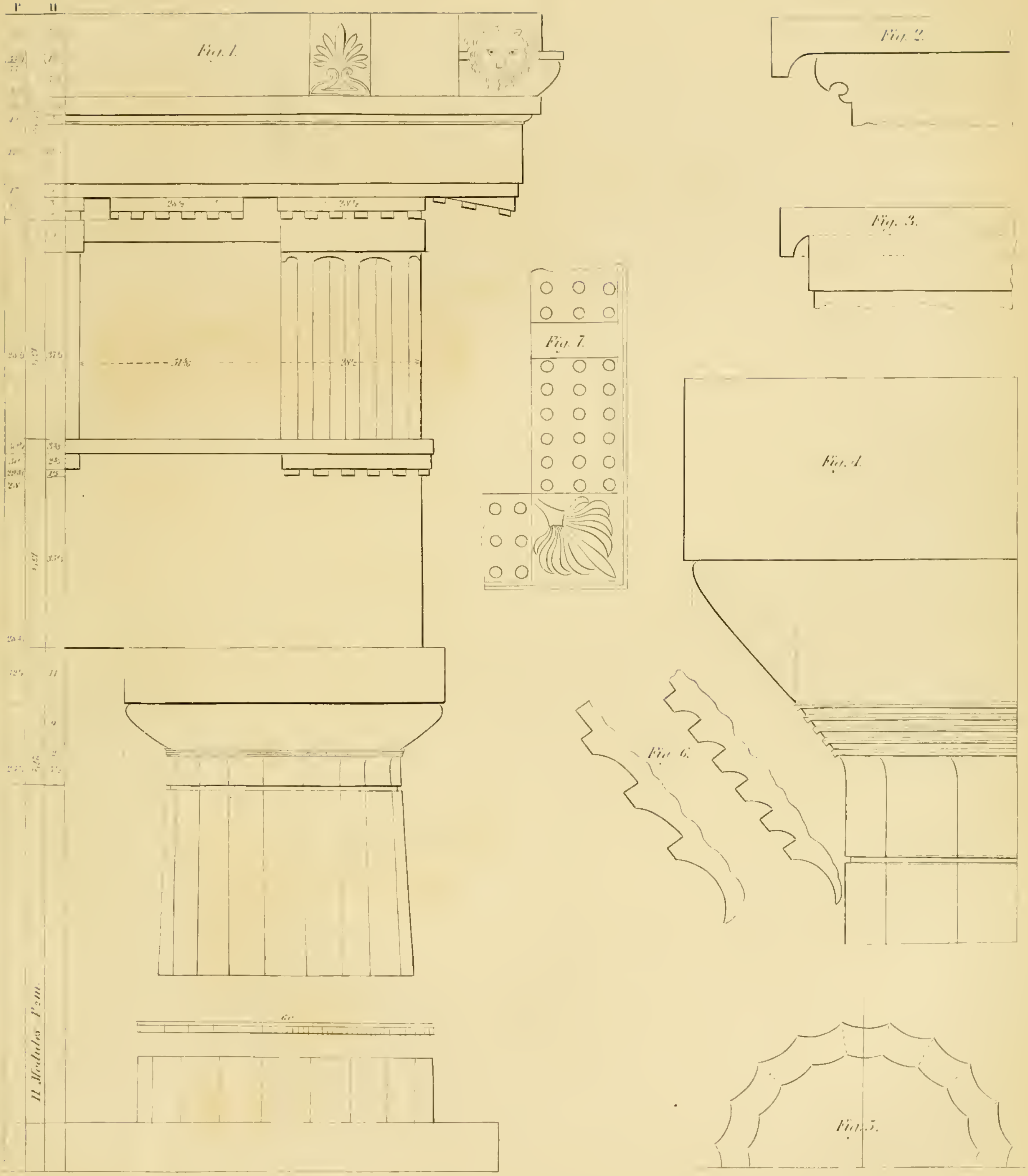
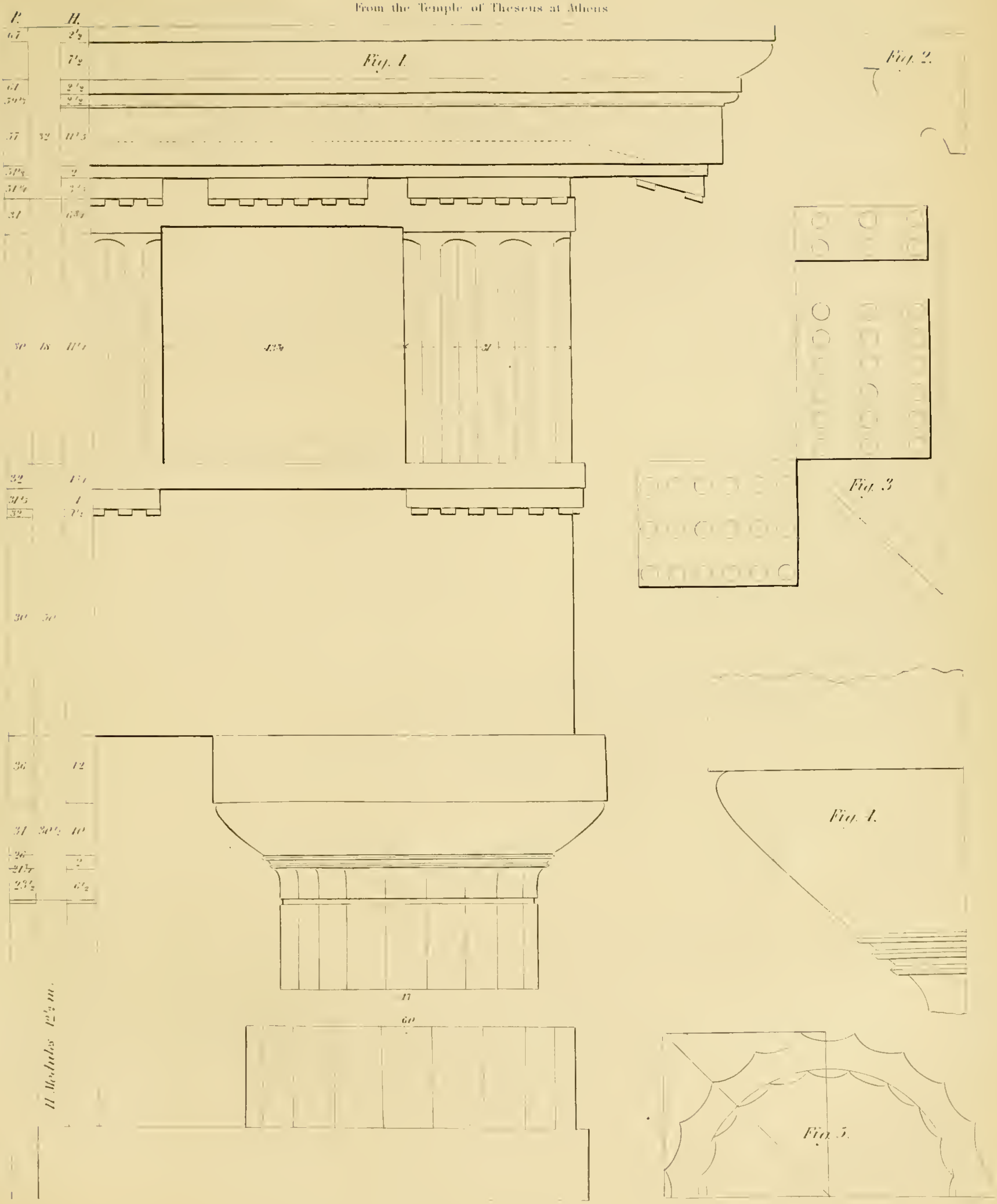


Fig. 1.
Fig. 2.
Fig. 3.
Fig. 4.
Fig. 5.
Fig. 6.
Fig. 7.
11 Modules

From the Temple of Theseus at Athens



one minute and a half high, to project beyond the mutules half a minute over this fillet; make the height of the corona one third of a module, or ten minutes, having a projecture over the fillet one minute; make the height of the small echinus one minute and a quarter; over the echinus make a fillet of the same height; over the fillet make another echinus six minutes and a half high, and two minutes will remain for the height of the fillet above the echinus.

In order to establish the proportions and true taste of the original Doric order, the following examples are taken from the most celebrated buildings now remaining of this order. The module is divided into thirty parts, or minutes; the measures are all numbered in these parts; the projections are reckoned from a line representing the axis of the column, and are figured at the extremities of each member.

Plate 44.

ELEVATION OF THE DORIC ORDER ON THE TEMPLE OF MINERVA, AT ATHENS, CALLED PARTHENON.

This temple, dedicated to Minerva, the chief goddess of the Athenians, is the most beautiful piece of antiquity remaining. It was built by Pericles, who employed Ictimus and Callicrates for his architects. The entablature is charged with historical figures of admirable workmanship; the figures of the pediment, though seen at so great a height, appear to be as large as life, being in alto rilievo, and well executed; the figure in the middle seems to have been made for Jupiter, its right arm being broken off, which probably held the thunder. It is likely that between his legs was placed the eagle; for the beard, and majesty, and expression of his countenance, and the figure being naked, as he was usually represented by the Greeks, sufficiently show it to have been made for Jupiter. At his right hand is another figure, covered half way down the legs, coming towards him, which perhaps was a Victory, leading the horses of Minerva's triumphal chariot, which follows it. The horses are finished with great art; the vigor and spirit peculiar to those animals seem here to receive addition, as if inspired by the goddess they drew. Minerva, in the chariot, is represented as the goddess of learning rather than of war, without helmet, buckler, or a Medusa's head on her breast, as Pausanias describes her image within the temple. Behind her is another figure of a woman sitting. The next two figures in the corner are the Emperor Hadrian, and his empress Sabina. On the left hand of Jupiter are five or six figures, which appear to be an assembly of the gods, where Jupiter introduces Minerva, and acknowledges her his daughter.

The pediment at the other end of the temple was adorned with figures, expressing Minerva's contest with Neptune about who should name the city of Athens, of which there only remains a part of a sea horse.

The frieze is charged with basso rilievos, of excellent workmanship, on which are represented the battles of the Athenians with the Centaurs; these appear to be as old as the temple itself.

Within the portico on high, and on the outside of the cella of the temple, is another border of basso rilievos around it, at least on the north and south sides of it, which is without doubt as ancient as the temple, and of admirable workmanship, but not in so high a rilievo as the other. On it are represented sacrifices, processions, and other ceremonies of the heathen worship.

This temple is now turned into a Turkish mosque.

Fig. 1. Elevation of the Doric order; the proportions of the parts in numbers.

Fig. 2 is a design, showing the order, with the column and entablature entire.

Plate 45.

Fig. 1. This example shows the return of the flank at the angle of the building. The figures in the metope are omitted.

Figs. 2 and 3 show the forms of the moulding and upper part of the cornice.

Fig. 4. Elevation of the capital, and of striking the ovolo by conic sections.

Fig. 5. Section of one half the column.

Fig. 6. Section through the annulets, of a large size.

Fig. 7. Plan of the soffit inverted.

Plate 46.

ELEVATION OF THE DORIC ORDER ON THE TEMPLE OF THESEUS, AT ATHENS.

This temple is one of the most ancient examples of the Doric order now existing; it was erected about ten years after the battle of Salamis, by Cimon, the son of Miltiades. The ceiling of the porch is re-

markable for its construction; there are great beams of marble, the upper sides of which are level with the bed of the cornice, and the ends corresponding exactly to the triglyphs in the frieze, which give the idea of the disposition of the timbers which were first used in buildings, and from which the Doric order is said to have had its origin.

This building is adorned with beautiful sculpture; the metopes of the frieze are charged with historical figures, on which are represented various exploits of Theseus; the battle he had with Sinis, the notorious robber, who dwelt in the Isthmus of Corinth. Theseus is represented making Sinis undergo those torments which he had inflicted on others.

In the basso rilievo is represented a man taking hold of another by his middle, and endeavoring to throw him down; this is, doubtless, intended to represent Theseus throwing Sciron from a rock; the combat of Theseus with the wild sow of Crommyon, which was killed by that hero. In another basso rilievo is represented a man presenting his hand to a woman, perhaps to express the rape of Ariana, or Helen, by Theseus.

Some others of the basso rilievos in the metopes are less distinguished. The two mentioned by Pausanius are still to be seen on the front of the temple; one represents the battle of the Athenians with the Amazons, the other the dispute of the Centaurs and the Lapithæ, in which Theseus kills a Centaur with his own hand.

The first seems to represent the instant when the Athenians granted peace to the Amazons, for there the women are represented as sitting.

The inside of the temple is not ornamented like the outside.

This temple is now a Greek church, dedicated to St. George, and is at present in high esteem among the Athenians.

Fig. 1. The elevation of the order, with the heights and projections of the members in numbers.

The figures in the metopes are omitted.

Fig. 2. Represents the ovolo above the facia of the cornice.

Fig. 3. Plan of the soffit inverted.

Fig. 4. Plan of the ovolos and annulets of the column.

Fig. 5. Section of one half of the column.

Plate 47.

ELEVATION OF A GRECIAN DORIC, OF A LIGHTER PROPORTION THAN ANY OF THE PRECEDING, WITH THE PROPORTIONAL MEASURES IN NUMBERS.

The ratio of the parts of this elevation is the same as that on the portico of Philip, King of Macedon, in the Island of Delos; but the profile of the cornice differs as follows: Instead of the ovolo, which I have introduced in this example, a cima recta in the original occupies its place; and instead of the next ovolo under the fillet in this, there is in the original a cima reversa. The profile in this plate I conceive to be more beautiful than the original, as it will produce a greater variety of light and shade, and, consequently, the mouldings will be more clearly defined; but as the reader may be desirous of a knowledge of the true form and taste of the original mouldings, I have shown them in Fig. 3.

Fig. 1. Elevation, with the proportional measures in numbers.

Fig. 2. A section through the upper part of the cornice, showing the form and taste of the mouldings introduced into this elevation, by P. Nicholson.

Fig. 4. A section of the antæ of the same portico.

Plate 48.

FROM THE CHORAGIC MONUMENT OF THRASYLLUS.

Fig. 1. The proportional measures in number.

Fig. 2. Section through the cornice.

Fig. 3. Section through the capital.

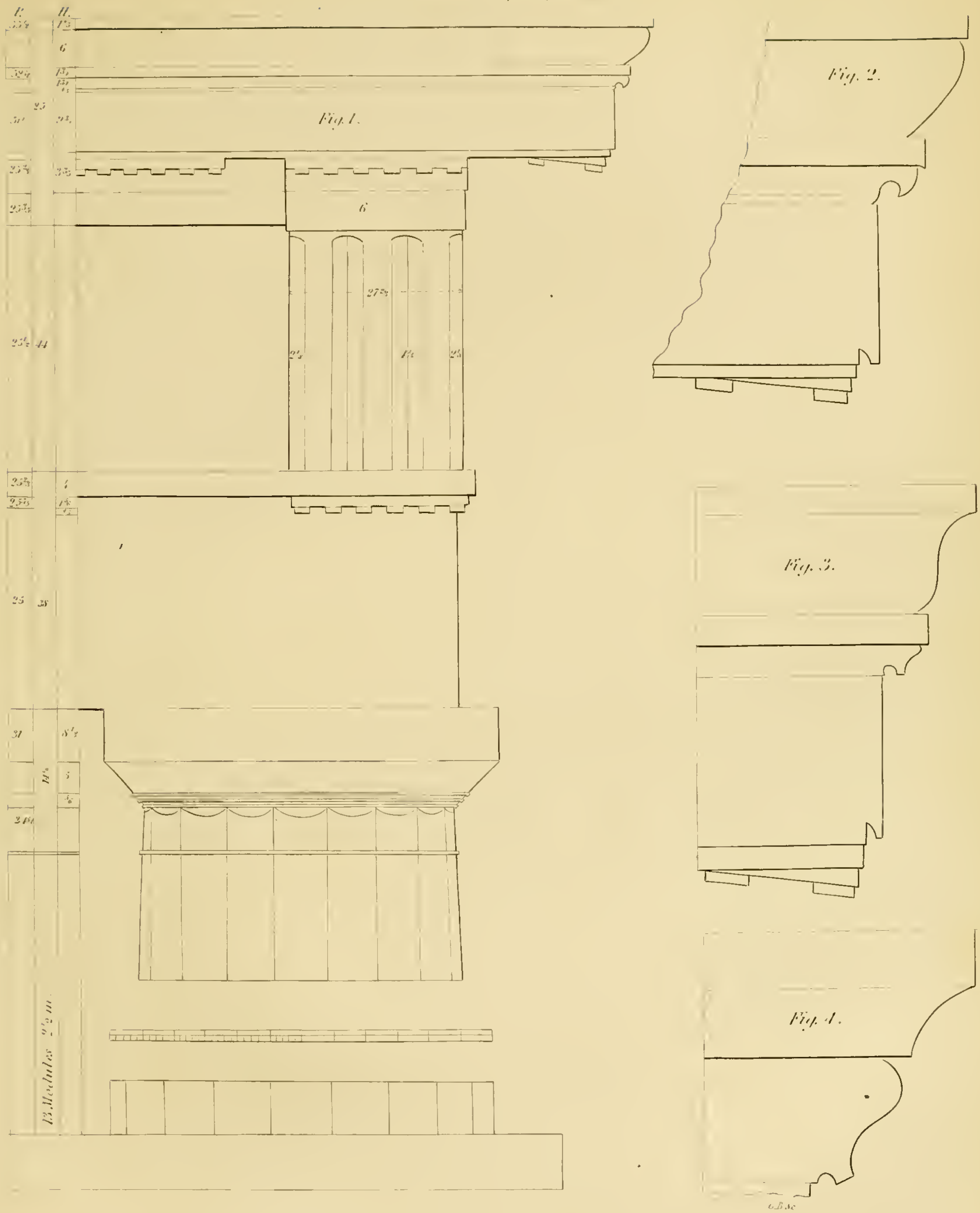
GRECIAN IONIC.

Plate 49.

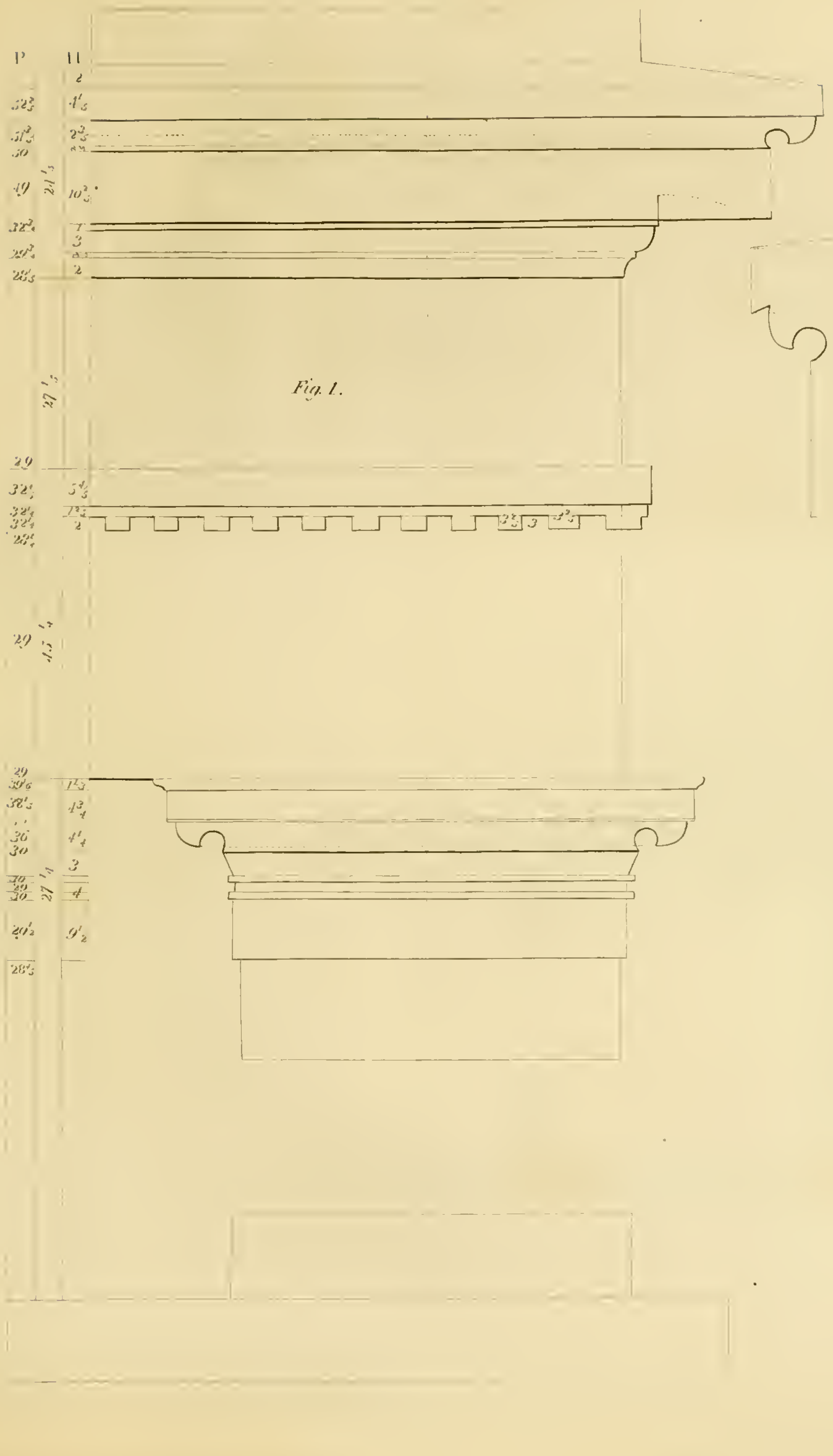
THE IONIC TEMPLE.

Fig. 1. A ground plan of the Temple on the Ilissus, with a portico at each end. The colums G G are wanting; but in the place where they stood circles are marked on the pavement, which are exactly of the same dimensions with the remaining columns, and were evidently designed as an accurate guide to the workmen, when they erected those columns which are now destroyed; for which reason it was thought necessary to make these circles likewise on the plan which is here given. The capitals of the antæ, belonging to the posticus or back front, remain entire, and are of the same form and dimensions with those of the portico, except only that the sides contiguous to the back wall of the cell are but half so broad as the faces next to the columns; whereas, in the antæ of the por-

From the Portico of Philip King of Macedon



From the Choragic Monument of Thrasyllus



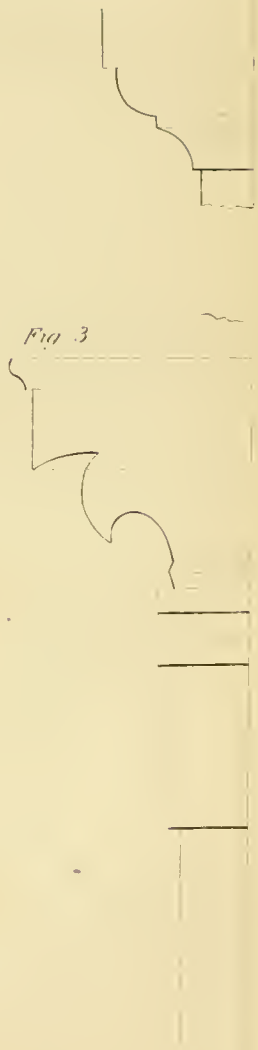
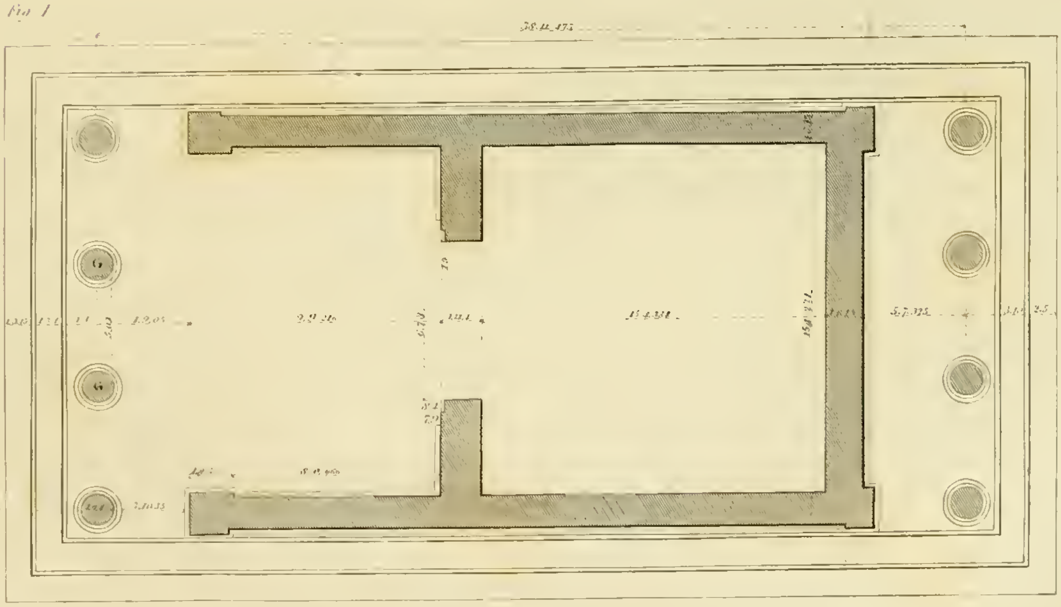
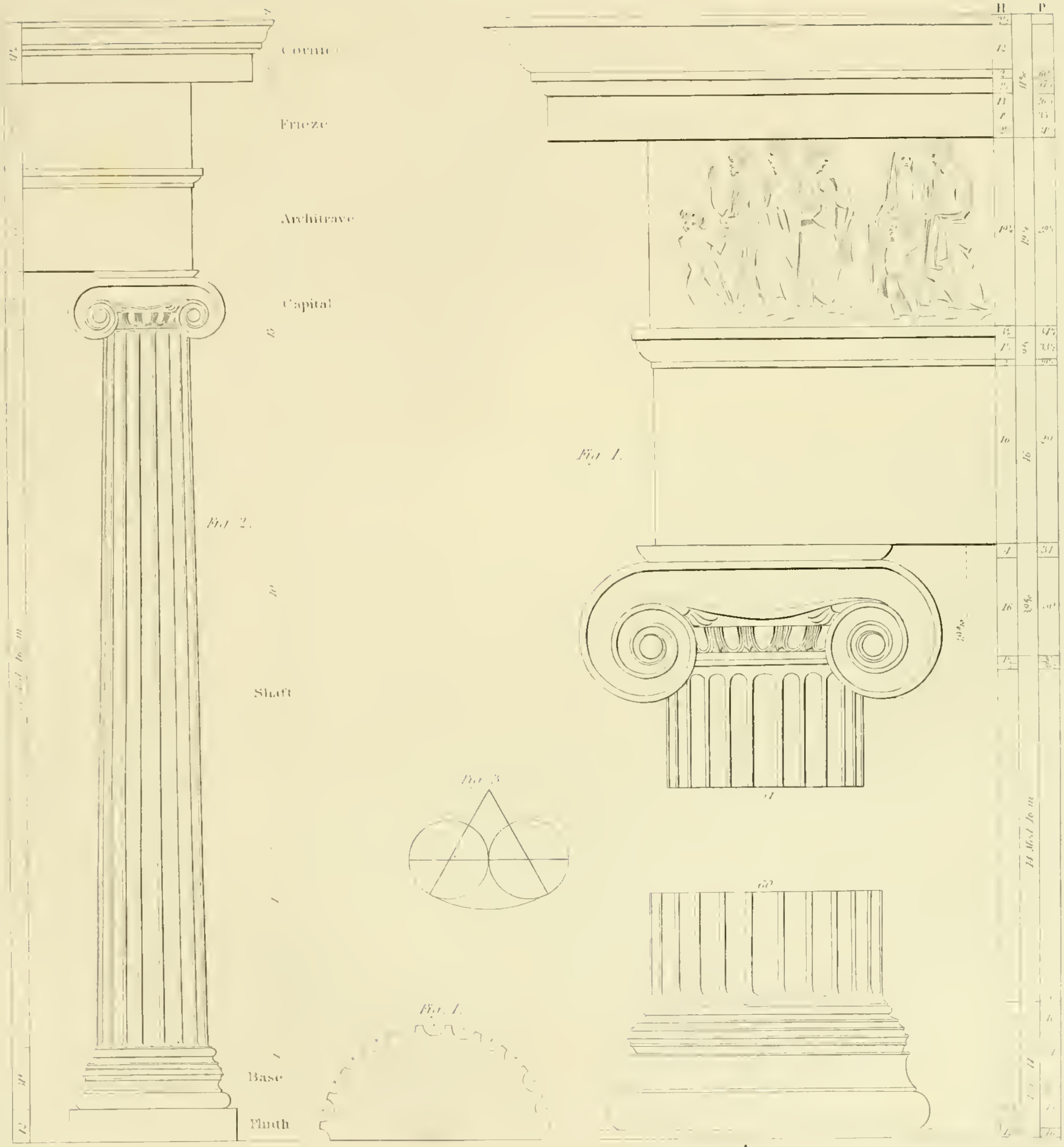


Fig. 1



From the Ionic Temple on the Ilissus



From the Ionic Temple on the river Ilisus

Fig. 2.

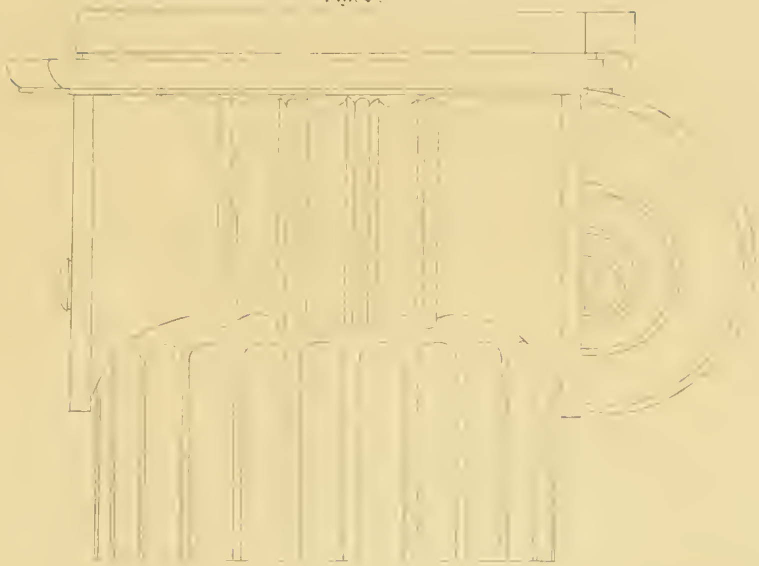
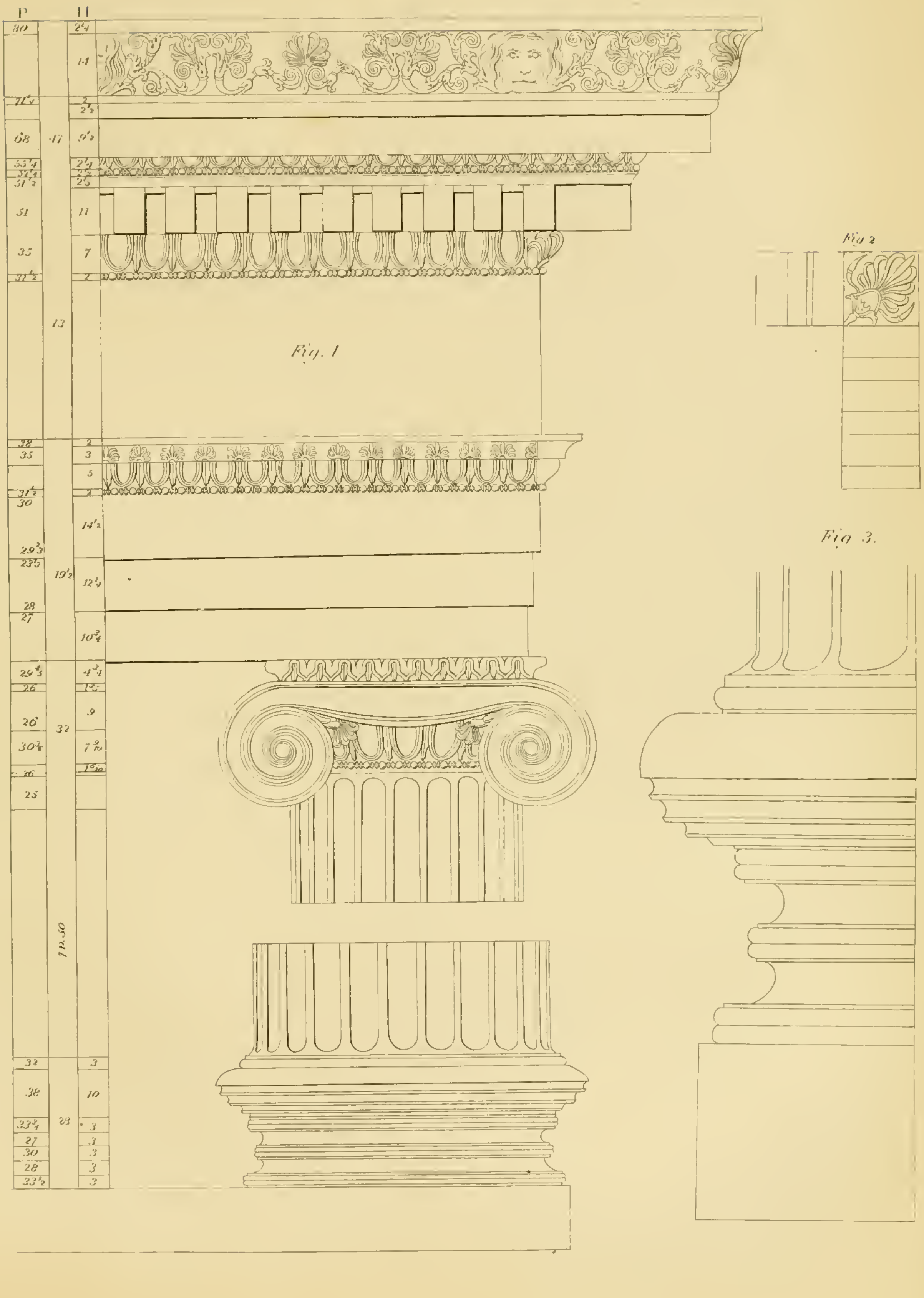


Fig. 1.

From the Temple of Minerva Polias at Priene



tico, the sides next the pronaos and the faces next the columns are equal. The architraves of the back front project considerably beyond the antæ, and there are sufficient remains of them to show exactly how far the columns of the back front were distant from the back wall of the cell.

Fig. 2. The elevation of the south side of the temple.

NOTE. — The ground plan and elevation are here given as measured by Stuart and Revett, in feet, inches, and decimals.

It has been already observed, in the general definitions of the orders, that every order consists of a column and an entablature; that every column consists of a base, a shaft, and a capital, except in the Doric, where the base is omitted; that every entablature consists of an architrave, a frieze, and a cornice; that the base, shaft, capital, architrave, frieze, and cornice are the principal members of an order; and that the peculiar mode or form of the members determines the particular name of the order. But since many of the mouldings are common to all the orders, and are generated in a similar manner, what has been said in the general definition, and also on the Doric order, will render it unnecessary to repeat the same things in the Ionic, as such mouldings cannot form any particular feature of any particular order. It is therefore shown, in the subjoined definitions, how these members ought to be modified, so that they may constitute the Ionic order.

DEFINITIONS.

1. If from the under side of the abacus of an order there project two or more spirals on each end of the front, in a plane, parallel to the frieze, so that the extremity of each shall be at the same distance from the axis of the column, and also two others upon the opposite side of the abacus, parallel to the former and projecting the same distance from the axis of the column, so that each of the spirals shall have the same number of revolutions, and equal and similar to each other, the projecting part contained between any two spirals is called a *volute.*

2. An order which has volutes and mouldings in the capital of the annular kind, and the ichnography of the abacus square, as in the Doric order, the architrave finishing of plain faciæ, and mouldings either plain or enriched, the frieze a plain surface, the cornice to consist of a cima recta, then a fillet and an echinus only; and if to the under side of the corona are hung a row of equal and similar parallelopipeds, equidistant from each other, whose fronts are in a plane parallel to the plane of the frieze, then each of these parallelopipeds is called a *dentil.*

3. An order so constructed is similar to that invented by the Ionians, and, consequently, is the Ionic order.

Plate 50.

FROM THE IONIC TEMPLE ON THE RIVER ILISSUS, AT ATHENS.

The simplicity and greatness of the parts, their judicious arrangement, the beautiful turning on the volutes, and the graceful curve of the hem hanging between them, render this one of the most beautiful and bold examples of this order.

The elegant base of the column, the grand proportion of the entablature, the massy mouldings of the cornice, and the spacious surface of the frieze, well adapted for sculptured ornaments, and the architrave for its strength, as it is not broken in two or more faciæ, are considerations which should recommend this example.

Fig. 1. The elevation of the order and details figured in proportional parts for practice.

Fig. 2. A drawing of the order, by dividing the whole height into twenty-one parts, which are disposed of in modules and minutes, as shown in the example; one of the parts makes a module, or thirty minutes.

Fig. 3 shows how to form the curve of the fluting; the Grecians used the ellipsis form, while the Romans as uniformly made use of a semicircle, as in Fig. 4.

Fig. 4. Explained the same as Fig. 3, in plate 58.

Plate 51.

Fig. 1. The capital inverted, of the different tastes of forming the volutes.

Fig. 2. The elevation of the same.

Plate 52.

FROM THE TEMPLE OF MINERVA POLIAS, AT PRIENE, IN IONIA.

The small projection of the cima recta, and its great height, is of itself beautiful and well contrived for the ornament, as it is less obscured by the shadow from the concave and convex parts of the moulding. This small projecture is also well adapted for a low corona; for the greater the projecture of the cima recta, the more it will predominate over the corona, by the principles of optics; and, on the contrary, the less the projecture of the cima recta, the less it will predominate over the corona. It follows, therefore, that a low corona will require a cima recta of a

small projecture; but a greater height of the corona will require a greater projecture of the cima recta, and a less height. The dentils, which are a striking feature in this order, show here to very great advantage, their bold and singular projecture greatly relieving them from each other.

The architrave is well proportioned to itself, and also to the cornice; the capital is elegant, and the spirals of the volutes are beautifully drawn.

The surprising delicacy of the ornaments, and their bold relief, with the grand ratio of the parts and mouldings to each other, render this one of the most beautiful examples of the Ionic order.

Fig. 1. The elevation of this example, the proportional measures in numbers.

Fig. 2. Ichnography of the dentils.

Fig. 3. Profile of the mouldings in the base to a larger size.

The cimatium, or crown of the architrave, was taken from the designs of Mr. Wood, who visited this temple before Mr. Revett.

The base of the column is true Ionic: it has no plinth; the upper scotia is inverted, which diversifies and gives the contour a greater beauty than is the Vitruvian base, in which the scotiæ are one over the other, uninverted. The torus is elliptical, and fluted.

The eyes of the volutes are bored two inches and a half deep; the hem, or border, with its fillets resting on the echinus, and connecting with a graceful curve the spirals of the volutes, seeming to keep them secure in their place, adds greatly to the beauty of this capital.

Plate 53.

FROM THE TEMPLE OF MINERVA POLIAS, AT PRIENE.

Fig. 1. Section through the cornice of the pediment.

Fig. 2. Front of the cornice, showing the ornaments on the mouldings. It is remarkable, that the enrichment of the upper moulding differs from that on the lateral cornice.

Fig. 3. The mouldings of the capital, with their proportion in numbers.

Fig. 4. Volute, with the measure in feet, inches, and tenths.

Fig. 5. A section through the upper torus of the base, which is of an elliptical form, the transverse axis being inclined to the plane of the horizon.

Plate 54.

FROM THE SAME TEMPLE.

Fig. 1. The elevation of the front of the capital, to larger size.

Fig. 2. The ichnography of half of the capital.

Fig. 3. Side elevation of the same.

Plate 55.

FROM THE TEMPLE OF BACCHUS, AT TEOS, IN IONIA.

This temple was first begun of the Doric order, by Hermogenus; but afterwards he changed it into the Ionic, and dedicated it to Bacchus.

This example is drawn from accurate measures, taken from that celebrated building.

The dentils, in the cornice, add greatly to the character of the order.

Fig. 1. The elevation of the order. It may here be observed, that no measures have been taken of the parts which are marked in this example with letters, as none of them could be found. They are here supplied by mere conjecture.

The base of the columns. It is thought, from the little differences between the shaft at the base and that immediately under the capital, that the base which is here exhibited did not belong to the capital shown at Fig. 1, but to some of the interior columns; for the ancients always made the interior ranges of columns less in diameter than the exterior, as is to be found in the celebrated Athenian buildings, the Temple of Minerva, and the Propylea.

Fig. 2. Profile of one half the front of the capital, with the measure of the volute, and proportional measures in numbers.

Plate 56.

FROM THE TEMPLE OF MINERVA, AT ATHENS.

Fig. 1. Another example of a volute, showing the different sections and formation of the face mouldings thereof.

Fig. 2. A section through A B.

From the Temple of Minerva Polias at Priene

Fig. 1.

Fig. 2.

Fig. 3.

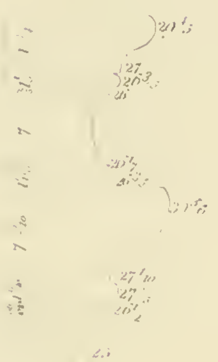


Fig. 4.

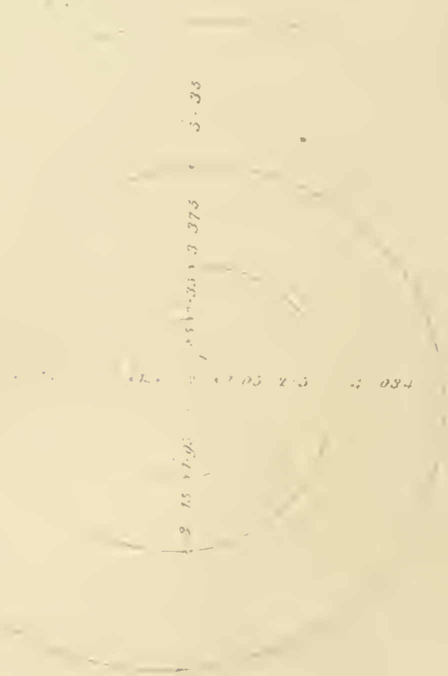


Fig.

From the Temple of Minerva Polias at Priene.

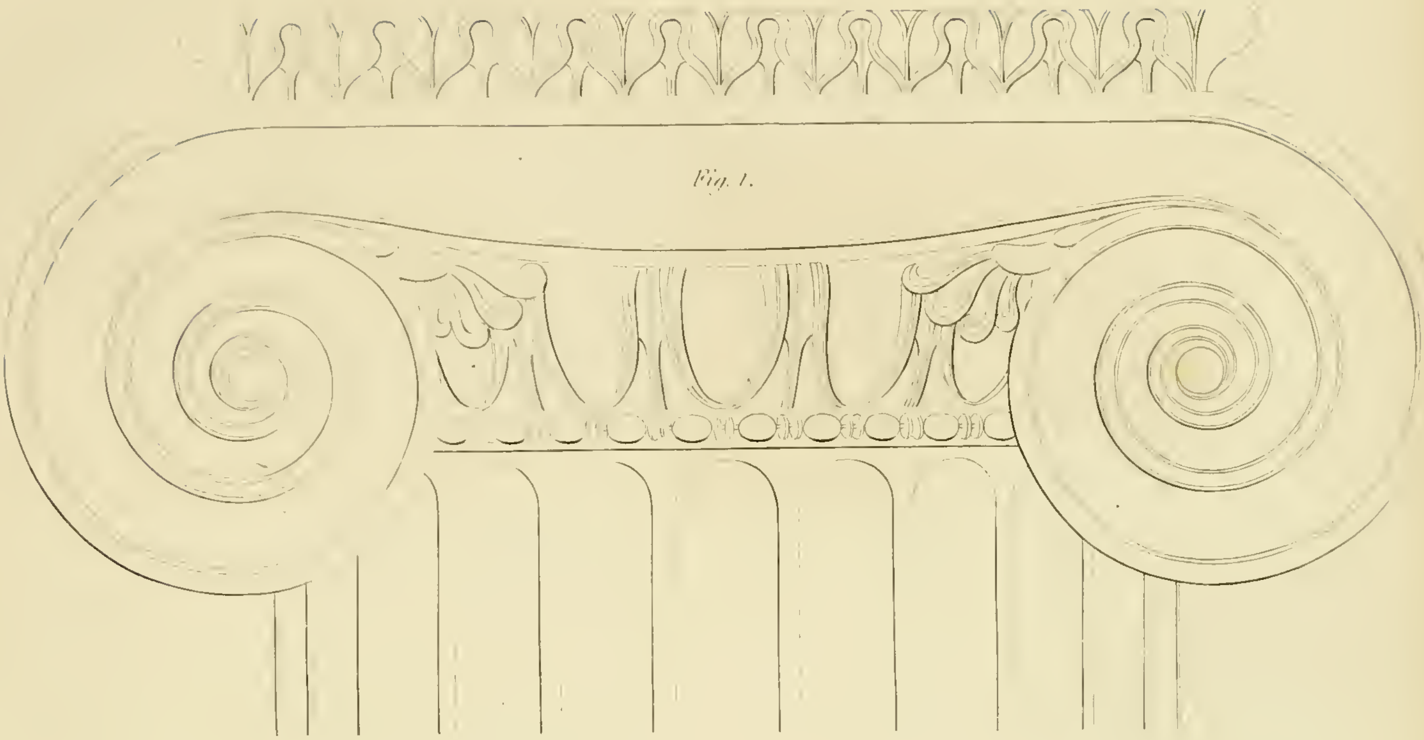


Fig. 1.

Fig. 2.

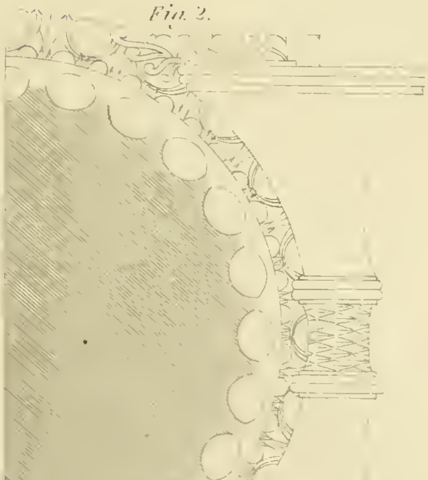
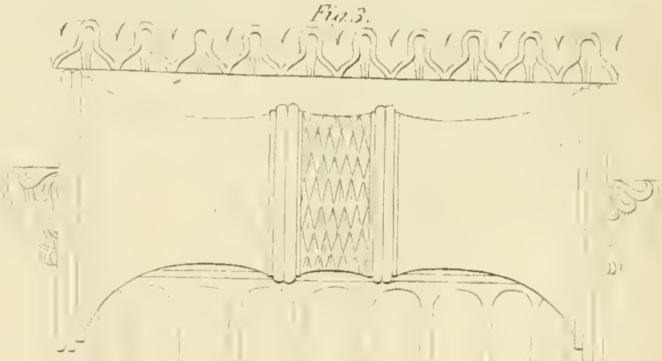
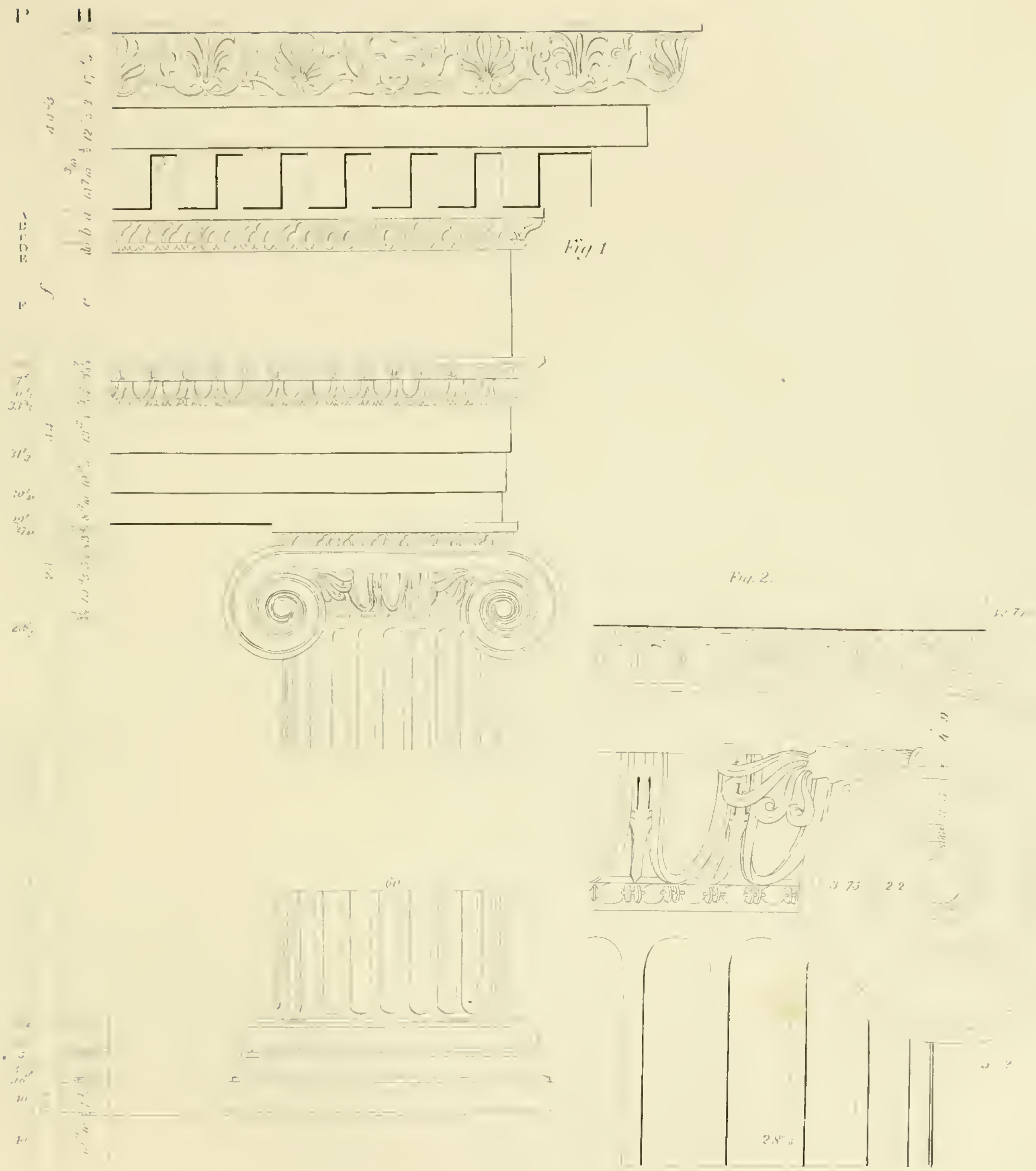


Fig. 3.



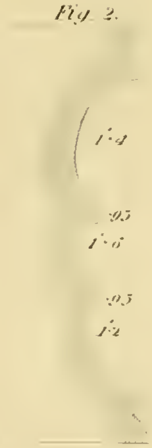
From the Temple of Bacchus at Teos



From the Temple of Minerva Polias at Athens

Fig. 1.

Fig. 2.



GRECIAN ARCHITECTURE.

CORINTHIAN ORDER.

On the architrave of the Choragic Monument at Lysicrates was the following inscription: —

"*Lysicrates, of Kikyna, the son of Lisithcides, was choragus,* (or gave the chorus at his own expense.) *The tribe of Akamantis obtained the victory in the chorus of boys. Theon was the performer on the flute; Lysades, an Athenian, was the teacher of the chorus. Evaenatus was archon.*"

From this we conclude that on some solemn festival, which was celebrated with games and plays, Lysicrates of Kikyna, a demos or borough town of the tribe of Akamantis, exhibited at his own expense, on behalf of the tribe to which he belonged, a musical or theatrical entertainment, in which the boys of Akamantis obtained the victory; also, that, in commemoration of the victory, this monument was erected to perpetuate the same to posterity, by the name of the archon, or magistrate, in whose time this took place. It appears that the building was erected about three hundred and thirty years before the Christian era, in the time of Demosthenes, Apelles, Lysippus, and Alexander the Great. The tripod seems to have been the peculiar reward bestowed by the people of Athens on that choragus who exhibited the best musical or theatrical entertainment; and we find this particular custom obtained for these tripods the name of choragic tripods. It was customary for the victor to dedicate the tripod he had won to some divinity, and to place it either on one of the temples already built, or on the top of some edifice erected and consecrated by him for the purpose. Thus they participated of the sanctity of the place, and were secured from injury or violence.

A tripod thus dedicated was always accompanied with an inscription, so that it became a permanent, authentic, and public monument of the victory and of the person who had obtained it.

Stuart and Revett deduce many circumstances to prove that it was erected for the above purpose, which appears rational and conclusive.

Description of the Choragic Monument.

The Choragic Monument of Lysicrates, which we are about to describe, is commonly called, by the modern Athenians, το Φαναρι του Δημοσθενιος, or the Lantern of Demosthenes.

This monument of antiquity, which is exquisitely wrought, stands near the eastern end of the Acropolis, and is partly enclosed in the hospitium of the Capuchins. It is composed of three distinct parts: first, a quadrangular basement; secondly, a circular colonnade, of which the intercolumniations were entirely closed; and thirdly, a *tholus*, or cupola, with the ornament that is on it. There is no entrance or aperture in the basement, which is entirely closed on every side. The basement supports the circular colonnade, and was constructed in the following manner: Six equal panels of white marble placed contiguous to each other, on a circular plan, formed a continued cylindrical wall, which was divided from top to bottom into six equal parts by the junction of the panels. On the whole length of each juncture was cut a semicircular groove, into which a Corinthian column was fitted with great exactness, so as effectually to conceal the junctures of the panels.* These columns projected somewhat more than half their diameters from the surface of the cylindrical wall, and have the Attic base. The shaft of the column is fluted in a singular manner; it contains thirteen flutes: the lower extremities of these flutings descend below their usual limits, and are cut into the apophyges, or scape of the column, and the upper extremities terminate in the form of leaves; the annular channel, immediately above them, which divides the shaft of the column from the capital, was probably filled with an astragal or collarino of bronze. Under this terminated the fluting in the form of an annular tier of leaves, turning outward from the shaft of the column.

This capital exhibits a specimen of the Grecian art. The annular tier of leaves springing from the neck in form of the palm, the acanthus forms the second tier with the flowers. In the third tier is shown the beautiful branches and the scrolls, terminating under the angular extremity of the abacus, the points of which are cut short; it in this respect, as well as in the disposition of the foliage, differs considerably from any other example of the Grecian Corinthian capitals.

The *entablature.* The architrave is divided into four divisions, the band or ogee and three parallel planes or faces projecting one over the other; the lower edges stand out one or two degrees from a perpendicular line.

The *frieze* of this entablature is ornamented with sculpture, representing the story of Bacchus and the Tyrrhenian pirates. The figure of Bacchus himself, the fauns and the satyrs who attended on the manifestation of his divinity, the chastisement of the pirates, their terror and their transformation into dolphins, are expressed in this basso rilievo with great spirit and elegance.

The *cornice* is very plain, composed of dentils and

* The two tripods are wrought in basso rilievo on each of the panels; they are probably of the kind described by Homer and Hesiod.

plain mouldings, in the place of the cima or cimatium, having an upright front; it is ornamented with scrolls and honeysuckle foliage in basso rilievo, in the Vitruvian style. This cornice is composed of several pieces of white marble, and bound together by a cupola of one entire piece.

The *cupola* is ornamented with elegant workmanship; its covering imitates that of thatch or of laurel leaves; the turret standing directly over the wall resembles a Vitruvian scroll; next above the laurel leaves, the covering of the dome, spring three scrolls, at equal distances from each other, in imitation of those branches in the capital shown in this plate. The flowers that ornament the top rise from the centre, and are composed of workmanship of foliage, which terminate in three divisions of scrolls, of great richness, on the top of which it is believed was supported the tripod gained as the prize, from the circumstance that cavities are cut on the three principal projections in an equilateral triangle, into which the feet of the tripod were probably fixed; and in the fourth cavity, which is in the centre, and much the largest, was erected a baluster to support the tripod.

Plate 57.

Fig. 1. This figure represents the elevation of the Grecian Corinthian order, from the Choragic Monument of Lysicrates, proportioned to modules and minutes.

Fig. 2. The inverted projection of the cornice.

Fig. 3. The base is attached to the basement.

Fig. 4. The capital inverted.

Plate 58.

To draw the flutes of the columns of the Doric order.

Divide the semi-circumference into ten equal parts; then with one of those parts, as a radius, and the extremities of any division, as at 3 and 4, describe arcs, cutting each other in C, and through C describe a circle, or a part, and draw lines from the centre, cutting that circle, which will give the centres for describing the flutes.

Or thus, for deeper Flutes.

Bisect any division, as 5, 6, at *f*; then on 5, with the distance 5 *f*, describe an arc *f* D, cutting the radius produced through 5 at D, and draw the radii through the points 5, 6, 7, 8, 9, 10, cutting that circle, which will give the centres of the flutes.

Fig. 2. The elevation drawn from the plan, Fig. 1.

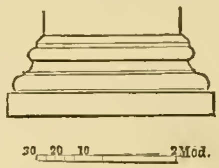
To draw the flutes of the Ionic and Corinthian orders.

Fig. 3. Divide the semi-circumference into twelve equal parts; divide any division, as between 5 and 6, into eight equal parts; then with a radius of three of these equal parts, on the points 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, as centres, describe the flutes, which will leave the fillets.

Fig. 4. The elevation drawn from the plan, Fig. 3.

BASES.

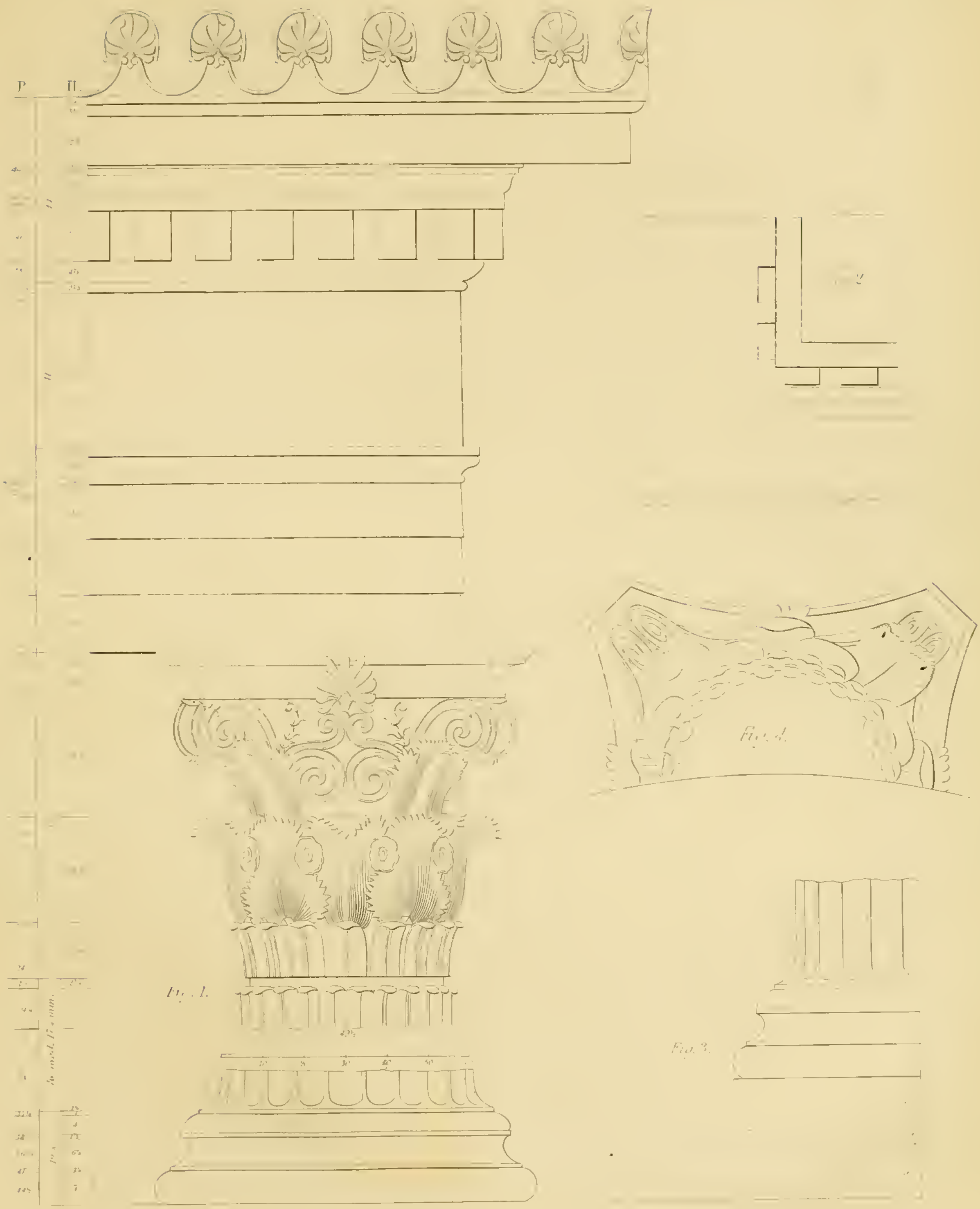
In no example of antiquity is the Doric column provided with a base. This circumstance, says Mr. Partington, has occasioned no small perplexity to some of those writers who seek, in every point, some analogy to the human figure. Vitruvius has indeed said that the base is a *shoe*, first invented to cover the nakedness of the matronly prototype of the Ionic order. "But," says Monsieur Le Clerc, "I must own I cannot consider a column without a base, comparing it to a man; but I am, at the same time, struck with the idea of a person without feet, rather than without shoes; for which reason, I am inclined to believe, either that the architects had not yet thought of employing bases to their columns, or that they omitted them in order to leave the pavement clear, the angles and projections of bases being stumbling-blocks to passengers, and so much the more troublesome, as the architects of those times frequently placed their columns very near each other, so that, had they been made with bases, the passages between them would have been extremely narrow and inconvenient." To supply this defect, as it is generally considered, most architects have employed the *Attic base*, which is common to all the orders except the Tuscan, though belonging, perhaps, more peculiarly to the Ionic. We have, therefore, here given a representation of it, as furnished by Mr. Partington, from Vignola.



It is seen that it consists of two tori, with a scotia and fillets between, the upper of which, in this version, resembles an inverted ovolo. The fillet, above the upper torus, is always connected with the shaft by a curve, as is also that under the capital, for which reason they are commonly considered as part of the shaft. The *plinth*, or square member beneath, is usually understood, in Roman architecture, as an indispensable appendage to the base, though Palladio has omitted it in his Corinthian order; but it is rarely found in the Greek specimens. To save this order, however, from the sad humiliation of being obliged to borrow a shoe, when required to wear one, Vignola provided it with this appendage. His base consists of one large torus, with one considerably smaller resting upon it, surmounted by the fillet.

PI. 57

From the Choragic Monument of Lysicrates



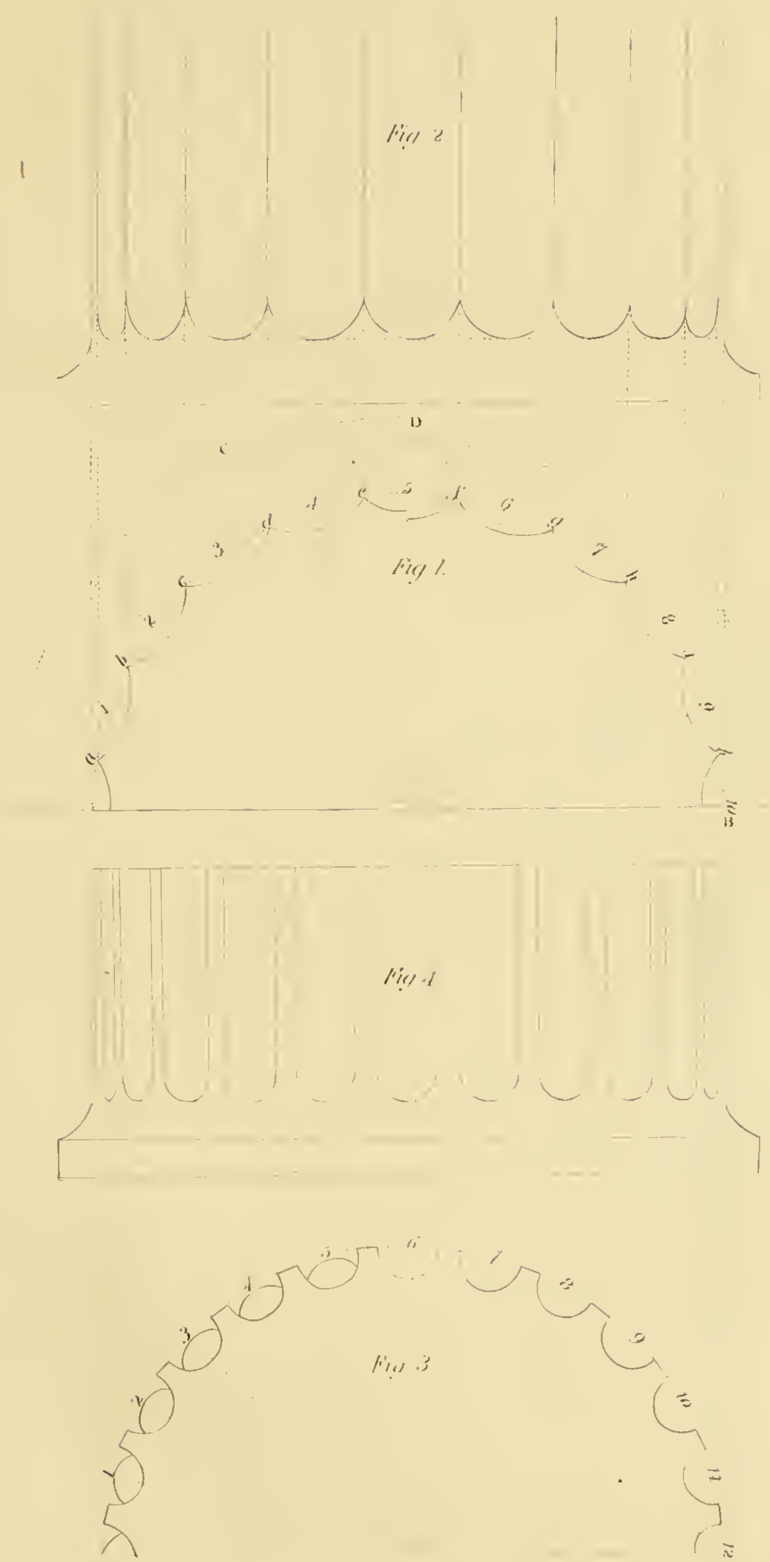
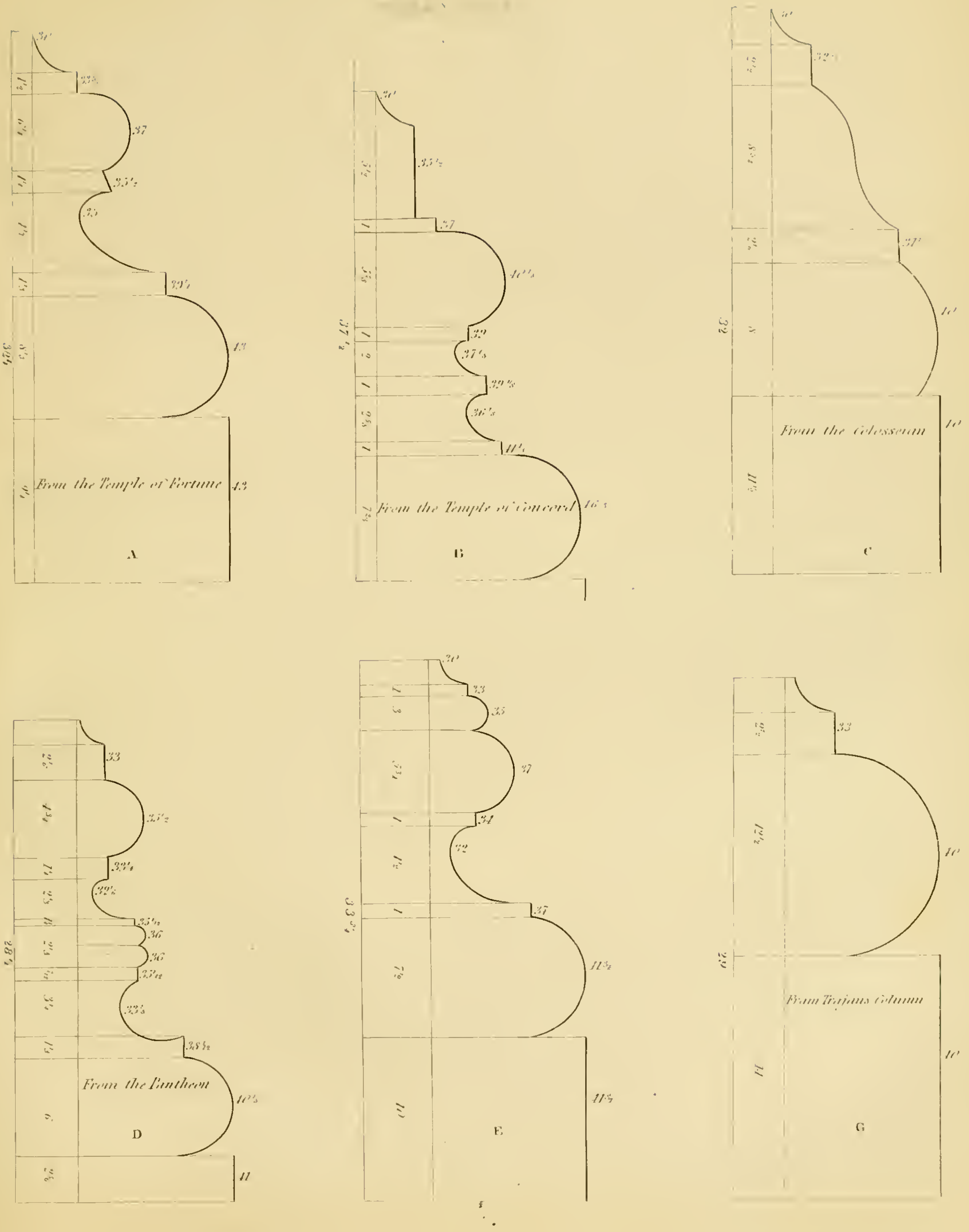


Fig. 2
D
Fig. 1.
Fig. 4
Fig. 3


From the Temple of Fortune
A
From the Temple of Concord
B
From the Colosseum
C
From the Pantheon
D
E
From Trajans Column
G

M. Le Clerc has, in the opinion of Mr. Partington, discovered the true reason why, at least in the latter Greek specimens, the base is omitted — namely, the very narrow intercolumniations. In the Greek order, alteration is not probable, and, perhaps, not desirable; but in the Roman, where this addition has long been provided for us, and the intercolumniations adjusted accordingly, the omission would be certainly improper.

ROMAN BASES.

Several designs for bases after the Roman taste are given on plate 59, which may be applied to columns, pilasters, and, in some instances, to rooms, chimney-pieces, &c.

Plate 59.

Fig. G. The Tuscan order.
Fig. E and A. The Doric.
Fig. B and C. The Ionic.
Fig. D. The Corinthian.

ENTABLATURES.

The orders consist of a composition of parts. When considered in gross numbers, they consist of two parts, viz., the column and entablature. These divisions are subdivided: the column comprises the base, capital, and their appendages, as shown in the orders. The entablature consists of the architrave, frieze, and cornice. The architrave, in all the orders, has the band. The Grecian Doric, however, does not furnish us with more than two divisions, — the band and frieze. The band, or fillet, which constitutes the upper part of the architrave, is projected under the triglyph; and an annulet is dropped from the fillet, a little on the frieze, to the soffit of which are attached six drops, as in the Grecian examples.

In the Ionic and Corinthian orders, the Greeks have divided the frieze into three projecting parts, as shown in the example from the Temple of Minerva Polias. The divisions are, 1st, 10¾; 2d, 12¼; 3d, 14½ minutes. The Romans, in this respect, have followed the Greeks, except in the proportions of the divisions; as seen in the Doric elevation found at Albano, near Rome; in the Diocletian Baths; and in the example from Andrea Palladio.

2d. The *frieze* or *entablature* is ornamented, in the Doric order, with triglyphs, and sometimes with sculpture, as shown in the example from the Temple of Theseus, at Athens. Aldrich has introduced triglyphs into the Composite order, which I consider a composition of the three orders. This practice, however, is seldom adopted; although there may not be much impropriety in borrowing from the Doric, as well as from the two higher orders.

The capital of the triglyph is from 4 to 6 minutes wide. The width of the triglyph is commonly from 28 to 30 minutes, having an angle of 135 degrees from the outer corners, cutting from the face 2½ minutes. The intermediate space is divided into five parts, the second and fourth being cut at right angles from the centre.

The frieze of the two higher orders, viz., the Ionic and Corinthian, afford a variety of ornaments, of which the Romans have been very profuse; as on the Temple of Fortuna Virilis, at Rome. See also the example from the Arch of Titus.

3d. *Cornices.* — This assemblage of parts affords much variety, from the plain bed mould, mutules, dentils, and modillions. The mutules are common in the Doric planceer. The dentils are common in the Ionic, and are placed between the hollow and the quarter round, as shown in the bed mould. An example of this is found in the Temple of Fortuna Virilis, and in the Coliseum, at Rome. The quarter round is sometimes ornamented with the egg and dart. The Corinthian order has dentils and modillions, as shown in the example from Jupiter Stator. The mouldings are often ornamented with carvings of various designs.

The facia, in the Grecian Doric, projects from 27 to 30 minutes from the triglyphs. In the Roman Doric, it sometimes projects from 34 to 37 minutes. The height of the facia varies from 7 to 11 minutes. The crown moulding is a cima recta, and, in modern times, the ovolo has been introduced in many instances, which is preferred on account of its superior strength, and the beautiful variety of light and shade which it presents to the eye. We find some examples overcharged with mouldings, which are not only offensive to the eye, but destroy the appearance of strength and proportion. An error of this kind is found in the Diocletian Baths, in which the graceful simplicity is lost, when compared with the Grecian Temple of Theseus. In the cornice, the facia has too much projection, and is not deep enough, and would have a far better appearance were the dentils quarter round, and bead left out. They are not considered as properly belonging to the Doric order. Palladio and others (as shown in some of the Roman examples given in this work) made use of a plain, simple bed mould, composed of a hollow and round, under the planceer. This is as much as belongs to the Doric.

In the Ionic, the Greeks have made use of the echinus, dentils, an angular fillet, and a quarter round, under the planceer, as in the example from the Temple of Minerva Polias. The extraordinary projection of the dentils, rising above a plain frieze, has a beautiful effect, as well as the modillions in the Corinthian order. This modillion is frequently ornamented with foliage; a decoration properly belonging to, and supporting, the planceer. The ornamented ovolo under the modillions, as found in the portico of the Pantheon, by its chaste appearance, occasioned by not adding a surplus of variety, is rendered one of the best specimens of the Romans. The example taken from the Temple of Jupiter Stator is very beautiful. The majestic proportions of the capital and entablature would give it the superiority, were it not overcharged with too much finery. The addition of dentils, however, can be no objection to its pleasing effect, as, in cities, eave cornices are not often viewed to advantage at a greater distance than the angle of forty-five degrees, and within that distance the ornamented planceer shows to good advantage. The proportions of cornices should invariably be regulated according to these distances. If at the angle of forty-five degrees, the height should be equal to its projections. If short of this, its projections should increase, in regular proportion, in all its members. The crown moulding of the cornices should be projected with some variation, — the Grecian ovolo at forty-five degrees, — but the cima recta should not project so much, in order to open it more to the rays of light; for if the swell does not receive a strong light, it is rendered obscure at any considerable height.

I have introduced in this place several designs for cornices, which may assist, in some measure, the fancy of those who may wish to vary from the original Greek and Roman styles and proportions. They may be executed on frontispieces, and many other places, to advantage.

Plate 60.

Presents five cornices, with the scale to which they are drawn. The scale is supposed to be the diameter of the shaft of the column, at the bottom; from which these designs are figured in proportional parts. Figs. 1 and 5 are plain planceers; 3 and 4 ornamented friezes and entablatures. No. 1, plan of the planceer of Figs. 3 and 4.

Plate 61.

Fig. 1. Design of a modillion cornice. No. 1, the modillion and manner of drawing it, viz.: From A radiate from 1 to 2; from B to 1 and 3; from C to 3 and 4, which completes the lower curve.

Fig. 2. A cornice without the entablature. No. 2, design of the planceer, with mutules and ornament.

Fig. 3. Design of a Doric entablature. No. 3, ornamented planceer.

Fig. 4. A Doric entablature and cornice. No. 4, mutules with a reset.

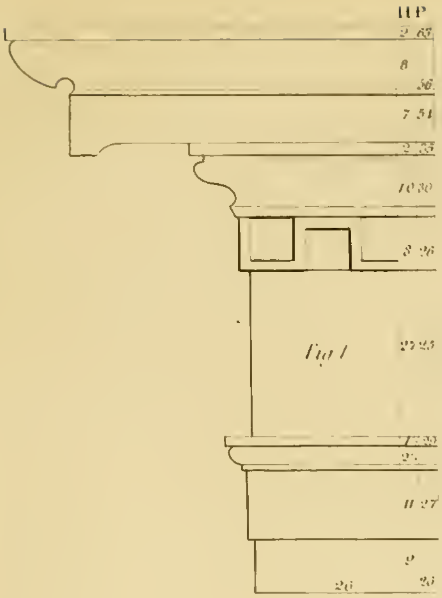
CHIMNEY-PIECES.

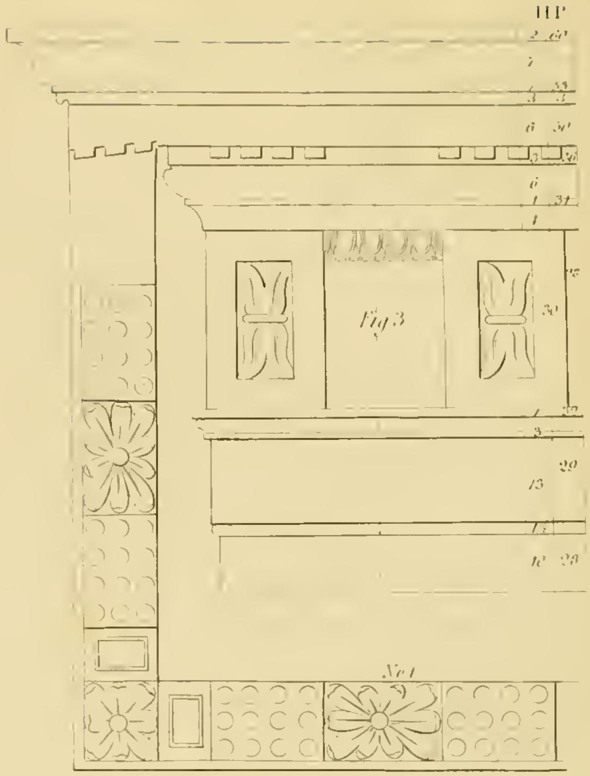
It is a remarkable fact that neither the Italian nor the French, nor indeed any of the continental nations, have ever excelled in compositions of chimney-pieces. It is believed that Inigo Jones, eminently distinguished among the architects of England, was the first who arrived at any great degree of perfection in this important branch of architectural science. Other architects have, since his time, wrought upon his ideas, or furnished good inventions of their own; and of our many ingenious and very able artists, whose province it is to execute magnificent chimney-pieces in marble, happily much in vogue, it may be said that, for taste of design and excellence of workmanship, they are not surpassed by those of any other nation. It was facetiously observed by Sir William Chambers, that chimney-pieces should be "so situated as to be immediately seen by those who enter, that they may not have the persons already in the room, who are generally seated about the fire, to search for." There is much good sense in this remark.

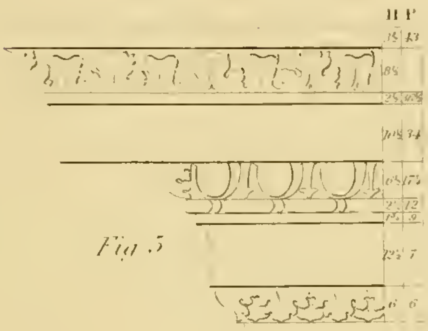
As the Egyptians, the Greeks, and the Romans, to whom architecture is so much indebted in other respects, lived in warm climates, where fires in the apartments were seldom or never necessary, they have thrown but little light on this branch of architecture. Amongst the antiquities of Italy, I do not recollect any remains of chimney-pieces. Palladio, indeed, mentions two — the one at Baia, and the other near Civita Vecchia, which stood in the middle of the room, and consisted of columns supporting architraves, whereon were placed the pyramids or funnels through which the smoke was conveyed. Scamozzi takes notice of three sorts of chimney-pieces used in Italy at his time. One of these he calls the Roman, the aperture of which is surrounded only with a clumsy architrave; another he calls Venetian, which is likewise adorned with an architrave, upon which are placed a frieze and cornice, and on the sides thereof are pilasters with consoles. The third sort he calls a Padiglione.

This last he particularly recommends where the walls are thin, if not being hollowed into the wall, as both the other sorts are, but composed of a projecting entablature supported by consoles, termini, or caryatides, on which the pyramid is placed. This sort of chimney-piece is still very common in Italy. The Dutch are very fond of it, and it may be found in many old English country-houses.

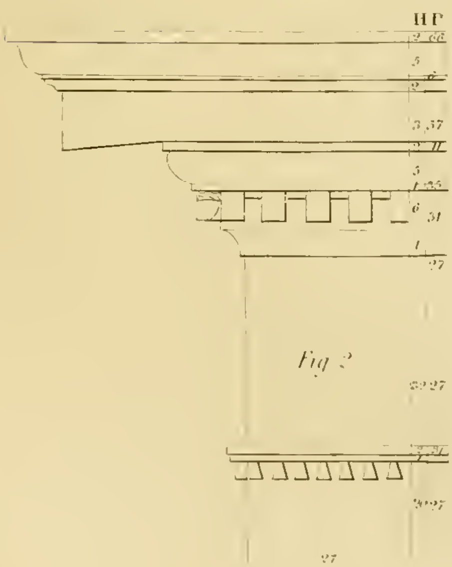
The size of the chimney-piece must depend upon the dimensions of the room wherein it is placed. In the smallest apartments, the width of the aperture is never made less than from three feet to three feet six inches; in rooms from twenty to twenty-four feet square, or of equal superficial dimensions, it may be four feet wide; in those of twenty-five to thirty, from four to four and a half; and in such as exceed these dimensions, the aperture may be extended to five, or five feet six inches; but should the room be extremely large, as is frequently the case with halls, galleries, and saloons, and one chimney of these last dimensions neither afford sufficient heat to warm the room, nor sufficient space round it for the company, it will be much more convenient, and far handsomer, to have two chimney-pieces of a moderate size, than a single one exceedingly large, all the parts of which would appear clumsy and disproportioned to the other decorations of the room. The chimney should always be "so situated as to be immediately seen by those who enter, that they may not have the persons already in the room, who are generally seated about the fire, to search for." The middle of the side partition wall is the most proper place in halls and saloons, and the other rooms of passage to which the principal entrances are commonly in the middle of the front, or of the back wall; but in drawing-rooms, dressing-rooms, and the like, the middle of the back wall is the best situation, the chimney being then farthest removed from the doors of communication. The case is the same with respect to galleries and libraries, whose doors of entrance are generally either at one or both ends. In

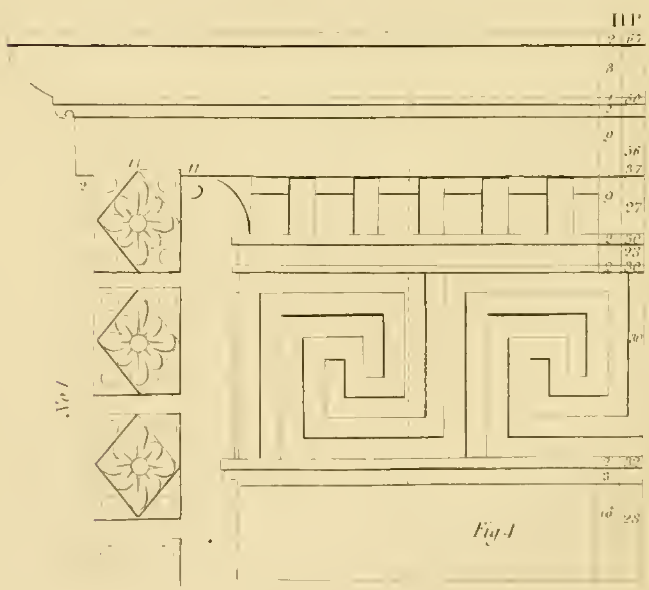


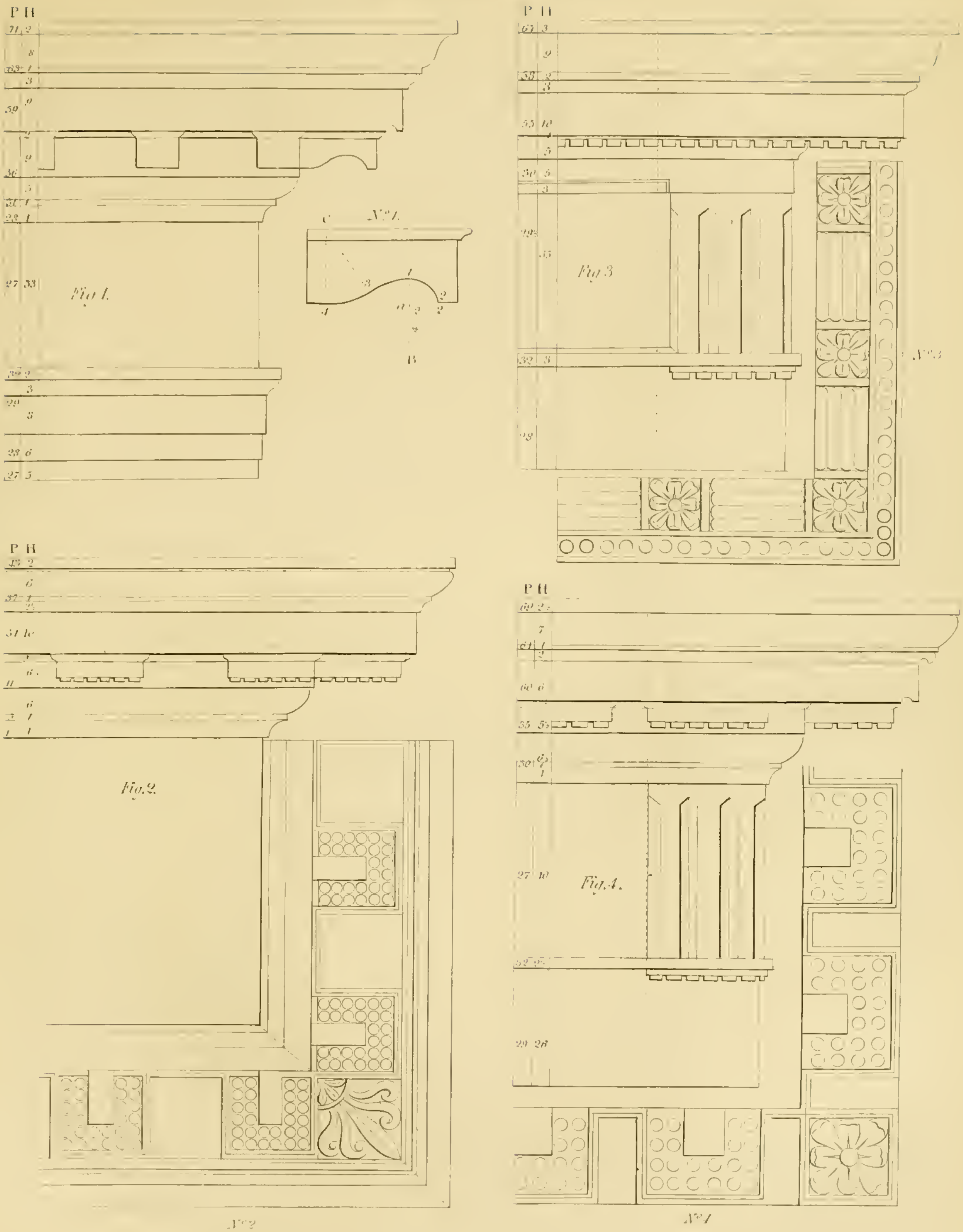




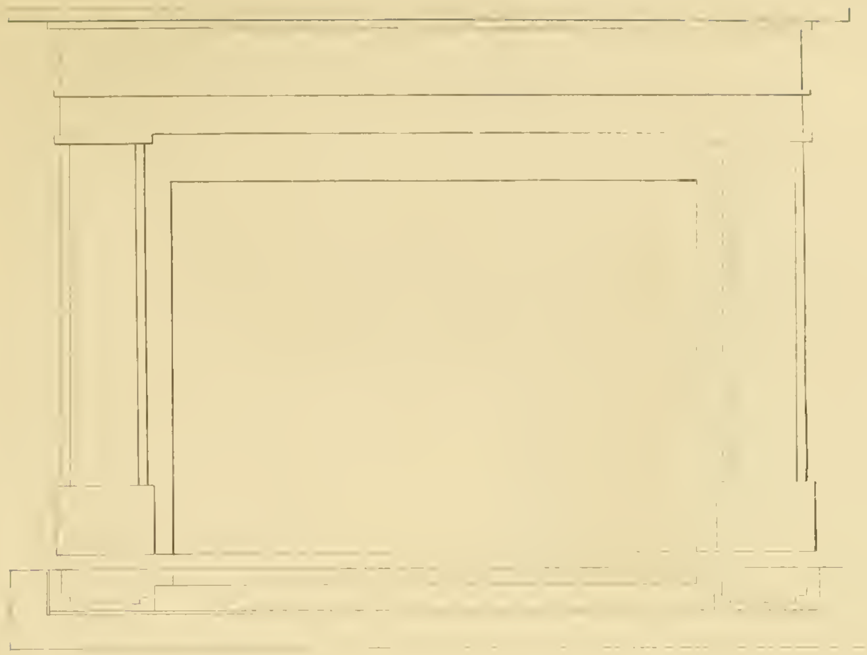
When Fig is used the entire height of the building should be divided into 16 parts and one of these into 54 parts, each of which is a minute





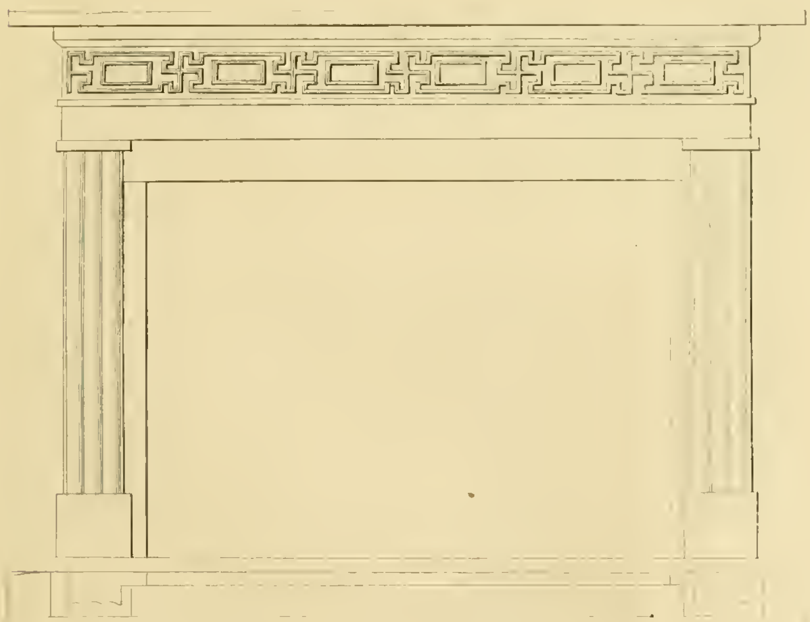


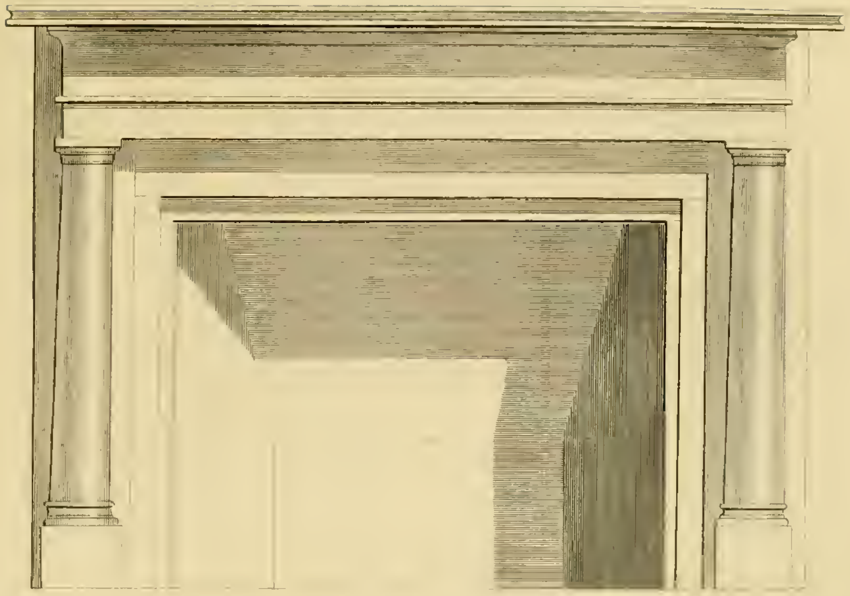
P H
Fig. 1.
Nº1.
Fig. 3
Nº3
Fig. 2.
Nº2
Fig. 4.
Nº4

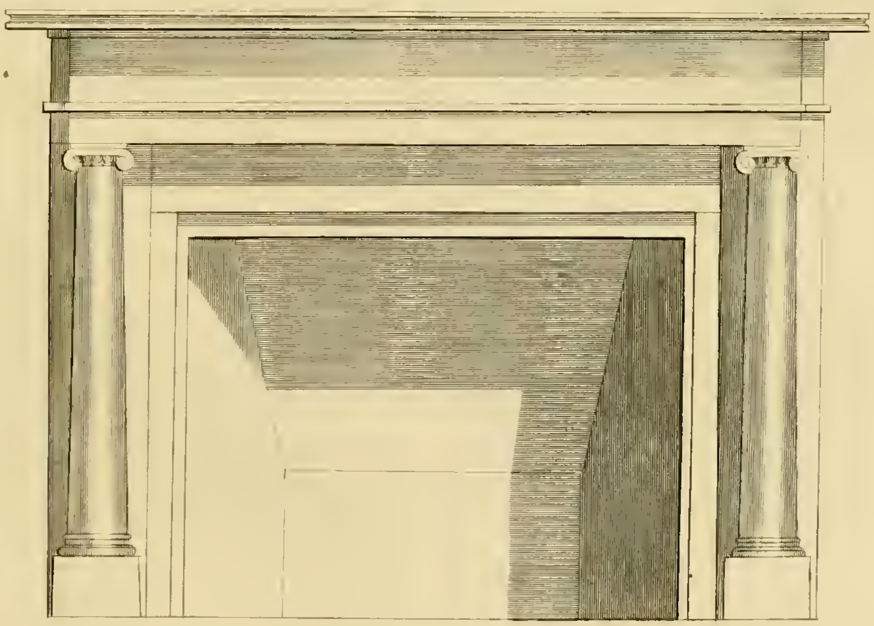


Scale of Feet and Inches

1 2 3 4 [illegible] 6







bed-chambers the chimney is always placed in the middle of one of the side partition walls, and in closets, or other very small places. It is, to save room, sometimes placed in one corner.

Whenever two chimneys are introduced in the same room, they must be regularly placed, either directly facing each other, if in different walls, or at equal distances from the centre of the wall in which they are both placed. The Italians frequently put their chimneys in the front walls between the windows, for the benefit of looking out while sitting by the fire.

The proportion of the apertures of chimney-pieces of a moderate size is generally near a square; in small ones, a trifle higher; and in larger ones, somewhat lower. Chimney-pieces are made either of stone or marble, or of a mixture of these with wood, scagliola, or molu, or some other unfragile substances. Those of marble are most costly, but they are also most elegant, and the only ones used in high-finished apartments, where they are seen either of white or variegated marbles, sometimes inlaid and decorated with the materials just mentioned. All their ornaments, figures, or profiles are to be made of the pure white sort; but their friezes, tablets, panels, shafts of columns, and other plain parts, may be of party-colored marbles, such as the yellow of Sienna, the brocatello of Spain, the jaspers of Sicily, and many other modern as well as antique marbles frequently to be had in this country. Festoons of flowers, trophies, and foliages, frets, and other such decorations cut in white statuary marble, and fixed on grounds of these, have a very good effect. But there should never be above two, or at the utmost three, different sorts of colors in the same chimney-piece, all brilliant and harmonizing with each other. In the inferior class of houses, and in upper chambers, wood is generally used in the construction of chimney-pieces, painted and varnished so as to resemble marble. The use of wooden chimney-pieces, when judiciously applied, materially lessens the expense, and answers every purpose of utility or ornament.

In many places, the wildest notions have been indulged in the designs of this part of architecture. Sometimes we see a chimney-piece, the shelf of which is supported on a numerous variety of mouldings, piled one above the other until they project nearly as much as the shelf itself; this, I contend, is useless and out of good taste, for they cannot be seen to any advantage, as in ordinary cases they fall below the eye, except when seated, and then they are so nearly on a level with it that they cannot be seen to any advantage. If, therefore, one half of the expense of mouldings should be laid out in the frieze and pilasters, or columns, they would have a much better appearance, and display a more refined taste.

Plate 62.

On this plate will be found two designs for common chimney-pieces, drawn to a scale of feet and inches.

Plate 63.

On this plate will be found two designs for chimney-pieces, as executed by Isaiah Rogers, Esq., in the Tremont House, Boston, Massachusetts, drawn from the same scale as plate 62.

DOORS.

In our northern climate, the fewer doors a room has the more it will be comfortably habitable; for as we have much more cold than hot weather, it is very necessary to make the rooms as close as possible, otherwise they will not be fit to live in the greater part of the year. Wherefore it will be advisable never to make either more windows or doors than are absolutely necessary. In this country, the real and feigned doors of a room, with their ornaments, frequently cover so great a part of the walls that there is no place left for either pictures or furniture.

Doors of entrance to private houses should not be less than three feet wide, nor more than six feet; but to churches, theatres, and other public structures, where there is a constant ingress and egress of people, and frequently great crowds, the apertures must be larger, and their width cannot be less than six feet, nor should it exceed ten or twelve.

In settling the dimensions of the apertures of doors, regard must be had to the architecture with which the door is surrounded. If it be placed in the intercolumniation of an order, the height of the aperture should never exceed three quarters of the space between the pavement and the architrave of the order, otherwise there cannot be room for the ornaments of the door. Nor should it ever be much less than two thirds of that space, for then there will be room sufficient to introduce both an entablature and a pediment without crowding; whereas, if it be less, it will appear trifling, and the intercolumniation will not be sufficiently filled. The apertures of doors placed in arches are regulated by the imposts, the top of the

cornice being generally made level with the top of the impost. And when doors are placed in the same line with windows, the top of the aperture should level with the tops of the apertures of the windows; or if that be not practicable without making the door much larger than is necessary, the aperture may be lower than those of the windows, and the tops of all the cornices made on the same level.

With regard to the situation of the principal entrance, Palladio observes, that it should be so placed as to admit of an easy communication with every part of the building. Scamozzi compares it to the mouth of an animal; and as nature, says he, has placed the one in the middle of the face, so the architect ought to place the other in the middle of the front of the edifice, that being the most noble situation, the most majestic and convenient. In several of the palaces at Rome, as those of the Pamfili in the Corso, and of the Bracciano, at Santi Apostoli, there are two principal entrances in the same aspect; but this is, in general, to be avoided, as it leaves strangers in doubt where to seek for the state apartments, which should always be contiguous to the principal entrance. In interior dispositions, the doors of communication must be situated, as much as possible, in a line; the advantages of which are, that it contributes towards the regularity of the decoration, and facilitates and shortens the passage through the apartments in summer; or on public occasions, when the doors are set open, it produces a free circulation of air, and likewise gives a much more splendid appearance to the apartments, by exposing to view at once the whole series of rooms, which is more particularly striking when the apartments are illuminated, as on occasions of balls, routs, or other rejoicings. There should, if possible, be a window at each end of the building, directly facing the line of the doors of communication, so that the view may be more extensive, and take in at once not only all the rooms, but likewise parts of the gardens, or other prospects surrounding the building; and whenever this is not practicable, it will do well to place mirrors at each end of the apartment, or to counterfeit doors, and fill them with large plates of glass, or with sashes and squares of looking-glass, as is the custom in France, which by reflection multiply the rooms, the doors, and other objects, making an apartment, though limited or small, appear very considerable.

The door of entrance from halls, vestibules, or antechambers, either to the principal apartment or to any even of the inferior ones, should be in the middle of the room, if possible, and facing a window; those that lead to galleries, or any other long rooms, should be in the middle of one of the ends; and in general, all entrances should be so contrived as to offer to view, at the first glance, the most magnificent and extensive prospect of the place they open into. The doors of communication from one room to another of the same apartment must be at least two feet distant from the front walls, that the tables placed against the piers, between the windows, or other pieces of furniture put there, may not stand in the way of those who pass. In bed-rooms, care must be taken to make no doors on the sides of the bed, unless it be to communicate with a water closet, wardrobe, bath, or other conveniency of that kind, as well on account of the draught of air as of the noise communicated through them, or attending their opening and shutting; both of which are always troublesome, and on some occasions dangerous. Neither ought doors to be placed near chimneys, for the same reasons, and as the opening of them would disturb those who sit by the fire.

In composing doors, regard must be had, both in their size and enrichments, to the place they lead to. Those that give entrance to churches, theatres, state apartments, or other places of consequence must be large and profusely enriched; but such as open to humbler habitations may be small and sparingly decorated, unless the nature of the building should require otherwise. Where several doors are in the same aspect, as on the inside of a hall, saloon, or gallery, they should be all of the same size and figure, unless there be many, in which case the principal ones, provided they stand in the middle of a side, or in the middle of the ends of the room, may be larger, of a different form, and more abundantly adorned than the rest. But, whenever more than two sorts are introduced in one room, it always tends to confuse the spectator.

The commonest sort of doors are made of pine, painted in various manners, and the better kind of them are of mahogany, or oak, or different sorts of rare wood, inlaid. With regard to their construction, strength, beauty, and straightness are to be considered; all which purposes are answered by composing them of several panels. The number of these must depend on the size of the door, which should like-

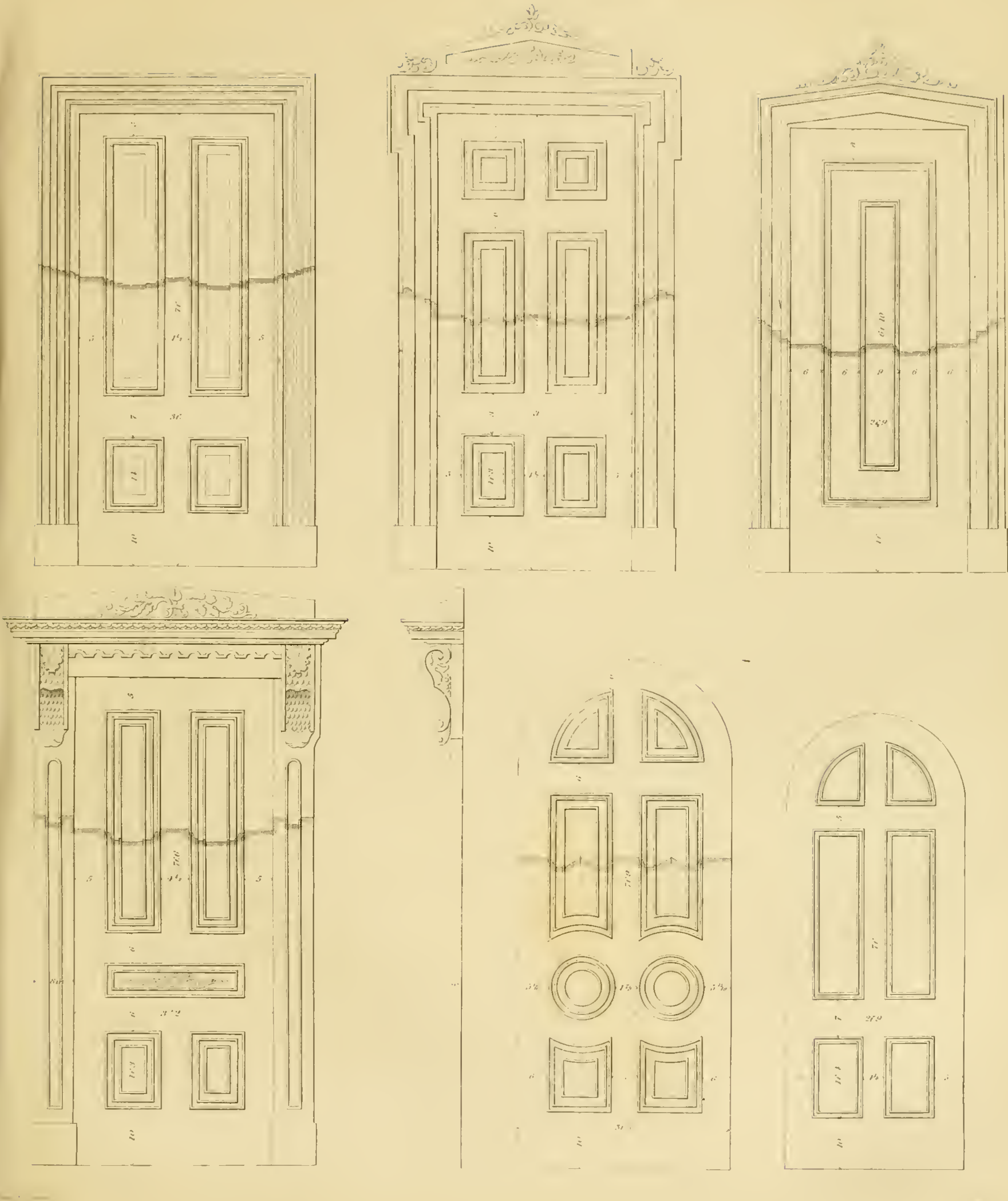


Fig. 1.

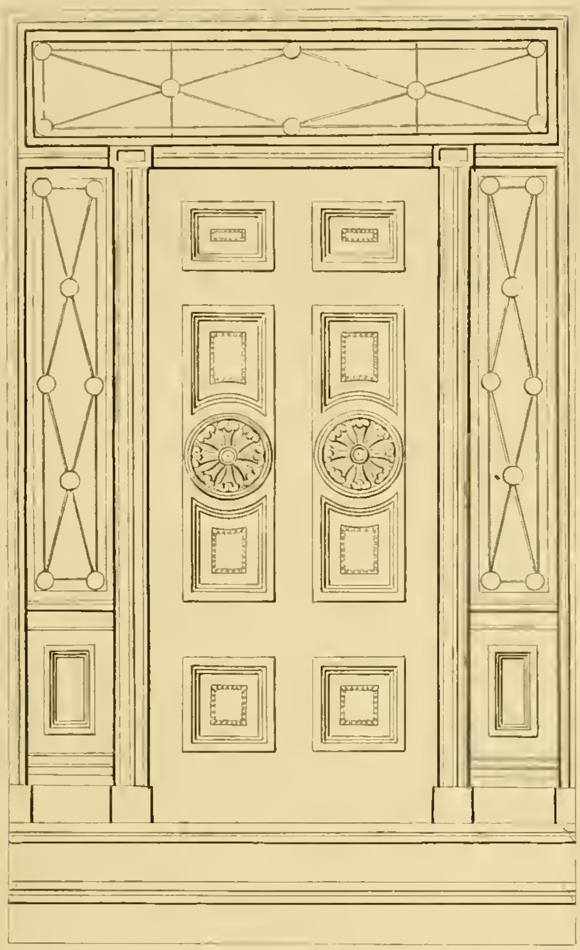


Fig. 2.

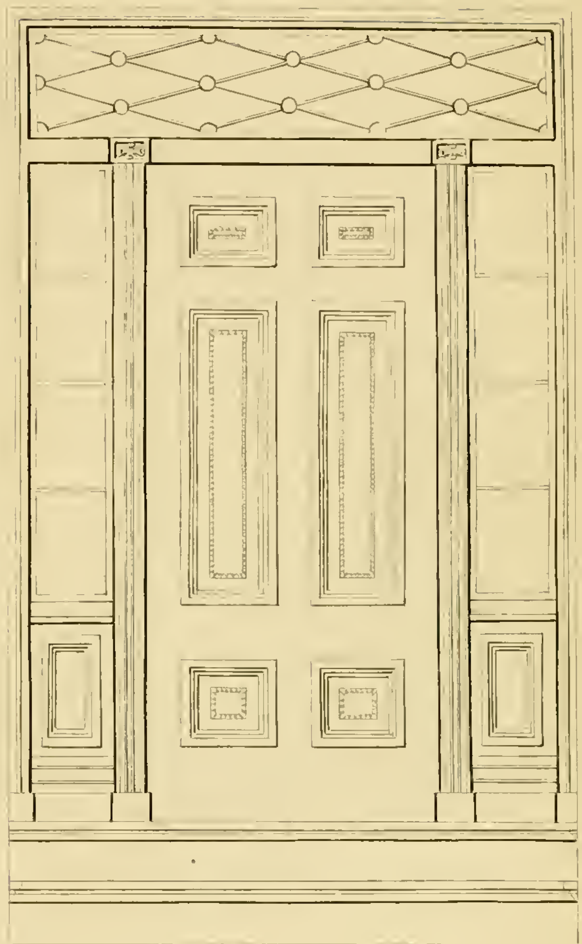


Fig. 3.

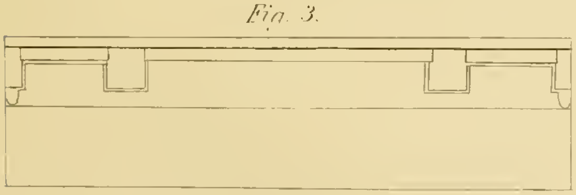


Fig. 4.

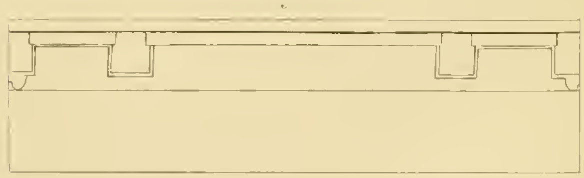


Fig. 5.

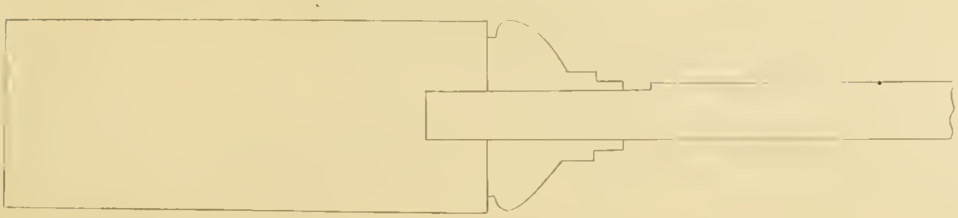
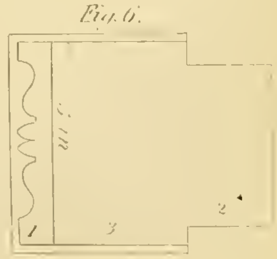


Fig. 6.



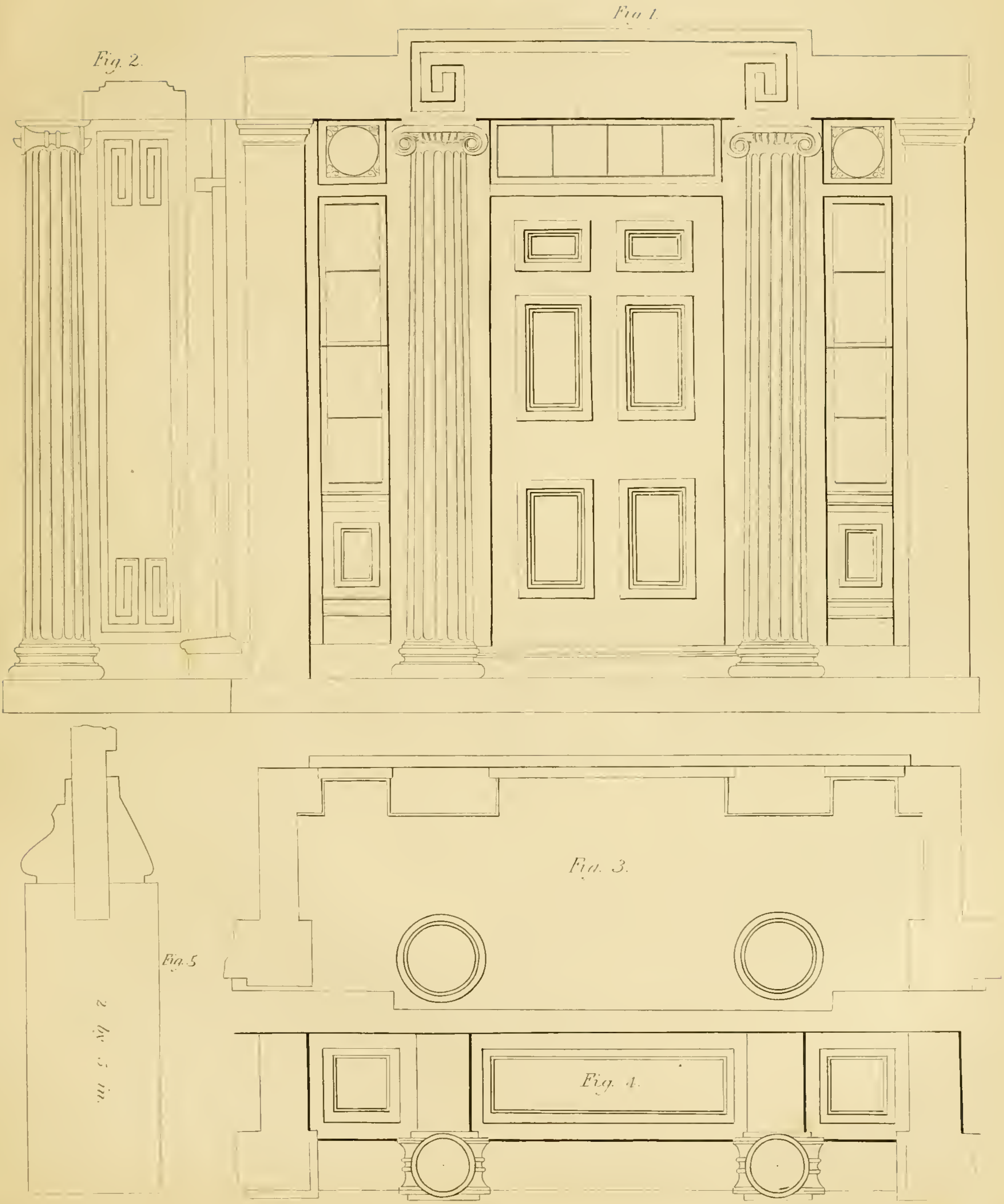


Fig. 1.
Fig. 2.
Fig. 3.
Fig. 4.
Fig. 5

wise regulate the thickness both of the panels and the framing. If the doors be adorned with ornaments of sculpture, as is sometimes usual in very rich buildings, they must either be sunk in, or kept very flat upon, the surface, both for the sake of lightness, and to prevent their being broken. The panels may be either raised or flat, and surrounded with one or two little plain or enriched mouldings, contained in the thickness of the framing, not projecting beyond it, as is sometimes seen in old buildings.

Doors that exceed three feet and a half in breadth are generally composed of two flaps, by which means each part is lighter; when open, does not project so far into the room; and when required, may be made to fold entirely into the thickness of the wall. It is to be observed, that all doors should open inwards; otherwise, in opening a door to give a person entrance, it must open in his face, and may chance to knock him down.

For a variety of doors, in the modern taste, see plates 64, 65, 66.

Plate 64.

On plate 64 will be found six designs for inside doors, with the finish. The proportions of each part are figured, and across each will be seen a sectional plan, showing panels, &c., either raised or sunken, as the case may be. A is an elevation of a circular head door, and is designed for an outside door. The architraves of each at 1, 2, and 3, are those on plate 30. — Editors.

Plate 65.

Figs. 1 and 2. Designs for outside doors.

Figs. 3 and 4. Horizontal section of the same, with a projection of the threshold, steps, and pilasters.

Fig. 5. Section of the style, panel, and moulding.

Fig. 6. Section of the pilaster and plinth.

Plate 66.

Fig. 1. Front door finished in the Ionic style, the pillars supporting the cap in the wall.

Fig. 2. The recess and side view of the column.

Fig. 3. The recess of the door from the column and step on which the pillars stand.

Fig. 4. The ceiling of the recess and inverted capitals of the column.

Fig. 5. Style, panel, and moulding of the door.

Good taste has taught us to avoid the multiplication of small members on inside finishing, and to adopt in their place plane surfaces, or appropriate mouldings of a proper size with their necessary arrangements, as it is much easier executing a proper finish of painting: the necessary application of a pumice stone or sand paper, to produce a smooth surface, is rendered impracticable, by numerous close quirks, without injuring the paint on the other parts. On a plane surface, the work is much easier cleansed; and by this style of finish, which rejects every thing that is mean and trifling, that manly character is given to the work which the refined taste of ancient and modern architects have so much admired.

The Proportions of the Architraves and Pilasters for inside Finish.

The architraves for windows and doors in any one apartment should be nearly of the same width, where a uniformity of appearance requires it. Add together the width of the door and of the window and the splay; find the mean width; then divide it by 7, which gives the width of the architrave; but where fancy pilasters are required, divide by 6, which gives one sixth of the width of the opening for the width of the pilasters. The designs in plate 30 give the full size that those in general use are executed.

CONSTRUCTION OF WINDOWS.

There has been in this branch of architecture, as well as all others, a variety of changes and modifications to suit the taste and fashion of the times. In civilized countries, convenience and beauty are consulted; whereas, in barbarous countries, strength and safety are their most necessary requisites. In this enlightened and happy country, every man of taste adorns his habitation with such as he may deem to be most convenient, economical, and ornamental. The enriching of windows with ornaments is of ancient date, and has been handed down to us in common with most of the grand principles of the arts and sciences.

The proportions of the apertures of windows depend upon their situation; their width in all the stories must be the same, but the different heights of the apartments make it necessary to vary the heights of the windows likewise. In the principal floor it may be from two and one eighth of the width to two and one third, according as the rooms have more or less elevation; but in the ground floor, where the apartments are usually somewhat lower, the aper-

tures of the windows should seldom exceed a double square; and when they are in a rustic basement, they are frequently made much lower. The windows of the second floor may be, in height, from one and a half of their width to one and four fifths; and those of attics or mezzanines, either a perfect square or somewhat lower. The character of the order in which the windows are employed, and that of the profiles with which they are enriched, must likewise, in some measure, be consulted, and the apertures be made more or less elevated, as the order of the whole decoration, or of the window itself, is more or less delicate.

The windows of the principal floor are generally most enriched. The simplest method of adorning them is with an architrave surrounding the aperture, covered with a frieze, and cornice suited thereto; but when the aperture is remarkably high with respect to its width, it becomes necessary to spread the ornaments on the sides thereof, by flanking the architrave with columns, pilasters, or consoles, in order to give the whole composition an agreeable proportion. The windows of the ground floor are sometimes left entirely plain, without any ornaments whatever; at other times, they are surrounded with an architrave, or with rustics, or have a regular architrave crowned with its frieze and cornice. Those of the second floor have generally an architrave carried entirely round the aperture; and the same is the method of adorning attic or mezzanine windows. But these two last have seldom or ever either frieze or cornice; whereas, the second floor windows, whenever their aperture approaches a double square, are often adorned with both.

The sills of the windows on the same floor should be on the same level, and raised above the floor from two feet nine inches to three feet at the very most. When the walls are thick, they should be reduced under the aperture of the windows, for the conveniency of looking out, and seats may be contrived to fit these recesses, as is the custom in many modern houses. In France, and now too often here, the windows are carried quite down to the floor, which, when the building is surrounded with gardens or other beautiful prospects, renders the apartments exceedingly pleasant in summer, but then they become exceedingly cold in winter; and the iron work, which in France, and latterly very much here, is placed on the outside by way of fence against accidents, ought never to take place where regular architecture is intended; for all the gilding and flourishing in the world can never make it tolerably accordant with the rest of the composition.

In regular built houses, the sills of the windows on the ground floor should be raised six feet above the pavement on the outside of the building, to hinder passengers from looking into the apartments; but when this cannot be done without raising the floor itself more than may be necessary, the lower parts of the windows may be furnished with blinds. The tops of the apertures of windows should never, within the apartments, be carried up close to the cornice of the room. A sufficient space ought always to be left for an architrave, or at least two or three inches between the architrave and cornice — a space usually occupied by the curtain lath.

The interval between the apertures of windows depends, in a great measure, on their enrichments. The width of the aperture is the smallest distance that can be between them, and twice that width should, in dwelling-houses, be the largest; otherwise, the rooms will not be sufficiently lighted, and the building will have rather the appearance of a prison than of a structure calculated for the conveniences and enjoyments of life. The purpose for which the building is intended should regulate the quantity of light to be introduced; and, therefore, in dwelling-houses, and all places where comfort and pleasure are the main purposes, there cannot be too much. But in sacred structures, which should affect the mind with awe and with reverence, or in other great works where grandeur of style is aimed at, it should be cautiously and rather sparingly distributed.

The windows nearest to the outward angles must be at least the width of their aperture distant from the angle, and a larger space will be still more seemly, and render the building more solid. In all the stories of the same aspect, the windows must be placed exactly one above the other, and those to the left symmetrize with those to the right, in size, situation, number, and figure.

The reasons for all these things are obvious enough, and, therefore, it is needless to mention them. The licentious practice of intermitting the architrave and frieze of an order in the intervals between the columns or pilasters, to make room for windows and their enrichments, which are carried close up to the cornice, can on no account whatever be suffered in

regular architecture, it being in the highest degree absurd to carry the windows above the ceiling, and great want of judgment in an architect to intermix and crowd together such a number of rich complicated parts as are those of the entablature of the order and the entablatures of the windows. Besides, the whole beauty of the order, when so mutilated, is destroyed, its proportions and figure being entirely changed. An interruption of the whole entablature to make room for a window, and converting it into an impost to the architrave, is a license equally unpardonable.

The common sort of builders in this country are extremely fond of variety in the ornaments of windows, and, indeed, in every other part of a building, imagining, probably, that it betrays a barrenness of invention to repeat the same object frequently. I have seen a house with only eleven windows in the whole front, and yet there were seven different sorts. At another place, the case is the same, there being seven or eight sorts of windows in the same aspect; and the like is to be met with in many other buildings, both in town and in the country. These inventive gentlemen would do well to give their attention to some professors of the mechanic arts, who, though exercising their talents on meaner objects, are nevertheless worthy of their imitation. No tailor thinks of employing seven or eight kinds of buttons on the same coat; a cutler will not make ten different sorts of knives for the same set; and if a cabinet maker be trusted to furnish a room, he seldom introduces more than one or two sorts of chairs: their practice is founded on experience; the general approbation of mankind is the standard they go by.

We do not discover, either in the works of antiquity or those of the great modern architects, any traces of this childish hankering after variety. The same object is frequently by them repeated a hundred times over; and this is one of the causes of that amazing grandeur, that noble simplicity, so much to be admired in their productions.

This sameness must, however, have its limits; for, when carried too far, the imagination of the beholder stagnates for want of occupation. In the most admired marks of architecture, we find the same objects generally continued throughout the same level: thus one order and one sort of windows or niches generally reign throughout the story; but in other stories, where the eye and the imagination necessarily assume a fresh course, the decoration is altered.

Sometimes, however, it may be necessary to increase the size, and vary the figures, of the windows, either in the centre break or in some other prominent part of a front, in order to light a saloon, a gallery, or a hall higher than the rest of the room. But then it will always be advisable to repeat the same form if simple, as an arch, three, five, or more times, according to the extent of the plan, so that the mind may be in some degree satiated before it is conducted to a new object.

Venetian windows and Venetian doors, too, are on some occasions necessary, particularly in small buildings, to light a hall, a vestibule, or such other rooms as cannot admit of two windows, and yet would not be sufficiently lighted with one. But where they can be avoided, it is best; for the columns which separate the large interval from those on the sides form such slender partitions, that, at a distance, they are scarcely perceived, and the whole looks like a large, irregular breach made in the wall; and, however advisable it may be to repeat the same form as has above been mentioned, the repetition of these Venetian windows should always be avoided.

The sashes of windows are generally made of pine, cherry, or mahogany, and sometimes of iron, copper, or other metals. Our artificers excel in these works; they make them very neatly, and though in appearance slight, very strong. The lights of glass are proportioned to the size of the windows, there being commonly three in width and four in height, whatever be the dimensions of the window; each sash is composed of two equal parts, placed one above the other, and either the lowermost, or both of them, being hung on pulleys and counterpoised with weights, and moved up and down with great ease, the weights being concealed.

The shutters are always within the apartments wherever beauty is aimed at, those on the outside destroying the appearance of the front. They are divided into several vertical slips, folding behind each other, for the conveniency of ranging or boxing them, when open, in the thickness of the wall. Each slip or fold is framed and composed of several panels, either raised or flat, surrounded with small mouldings contained in the thickness of the framing, which, when the profiles in the rocm are en

riched, should likewise be so, at least on the fold that faces the aperture, when the shutters are turned back; the front of which must stand flush with the inner edge of the architrave surrounding the window, all the other folds being ranged behind it. I have given, in plate 67, the mode of finishing window frames, sashes, and shutters.

Plate 67.

Fig. 1 *shows the disposition of the members of a window frame and shutters.*

No. 1. The outside moulding against the wall.
No. 2. The outside casing.
No. 3. The pulley style.
No. 4. The inside casing.
No. 5. The back casing.
No. 6. The parting slip.
No. 7. The parting bead.
No. 8, 8. The weights.
No. 9. The recess of the wall.
No. 10, 10, 10, 10. The styles of the shutters.
No. 11, 11. The panels of the shutters.
No. 12. The back furring for the splay of the window.
No. 13. The ground.
No. 14. Section of the pilaster.
No. 15. The back lining.
No. 16. The thickness of the plastering.

Fig. 2 *shows the disposition of shutters folding back on a right line with the plastering.*

No. 1. The inside casing.
No. 2. Hinge casing.
No. 3, 3, 3, 3. Styles of the shutters.
No. 4, 4. Panels.
No. 5. Back casing.
No. 6. Box casing.
No. 7. Plastering.
No. 8. Band moulding.

Fig. 3. *Section of part of a shutter.*

No. 1. The style.
No. 2. Panel.
No. 3. Moulding.

Fig. 4. *Moulding, different from Fig.* 3.

Fig. 5. *Section through the frame and sash, and shows the manner of setting the sash into the frame.*

No. 1. The manner of joining the soffit to the frame.
No. 2. Cap of the frame.
No. 3, 3. Casings of the frame.
No. 4. Top rail of the sash.
No. 5. Munten of the sash.
No. 6, 6. Meeting rails.
No. 7. Munten.
No. 8. Bottom rail.
No. 9. Window sill.
No. 10. Stop bead.
No. 11. Back.
No. 12. Back bead.
No. 13. Outside moulding.

Figs. 6 *and* 7. *Sections of sash muntens.*

Plate 68.

On plate 68 will be found a plan, elevation, and section of a French window, with the scale by which it was drawn. No. 1 shows the elevation; No. 2, the plan; No. 3, a section; No. 4, a section of a part of the sill and the sash; A is a small fillet to prevent the water being driven beneath the sash; and B is a channel to receive the water that may run down on the outside behind the fillet; the dotted line C is another channel at right angles with B, to take the water to the outside. B shows the manner of constructing the meeting styles. The finish for the window may be either of the architraves shown on plate 30; and the manner of constructing the shutters is shown on plate 67.

Plate 69.

Plate 69 is a design for an oriel window. Figure 1 shows the front elevation; figure 2, the side elevation; figure 3, the plan; and figure 4, the detail of the base. The scale is placed with the plan, by which the several parts may be ascertained.

Plate 70.

Plate 70 * is a part of the details of plate 69. Figs. 1 and 2 are the trusses at D and A, and B is a delineation of the leaf at C. Fig. 3 is a truss or console.

* This plate, with plate 69, was designed and drawn by Mr. Shaw, and we have inserted it as being the modern production of one who has the honor of being among the earliest of the American architectural writers. Mr. Shaw's first edition of Civil Architecture was published more than twenty-five years ago; and since then he has contributed, in no small degree, to the advancement of his much-beloved science, both practically and theoretically. He is now in the 65th year of his age; but, notwithstanding his advancement in years, his desire is as strong as ever for the application of the correct principles of architecture in buildings of every kind. —Editors.

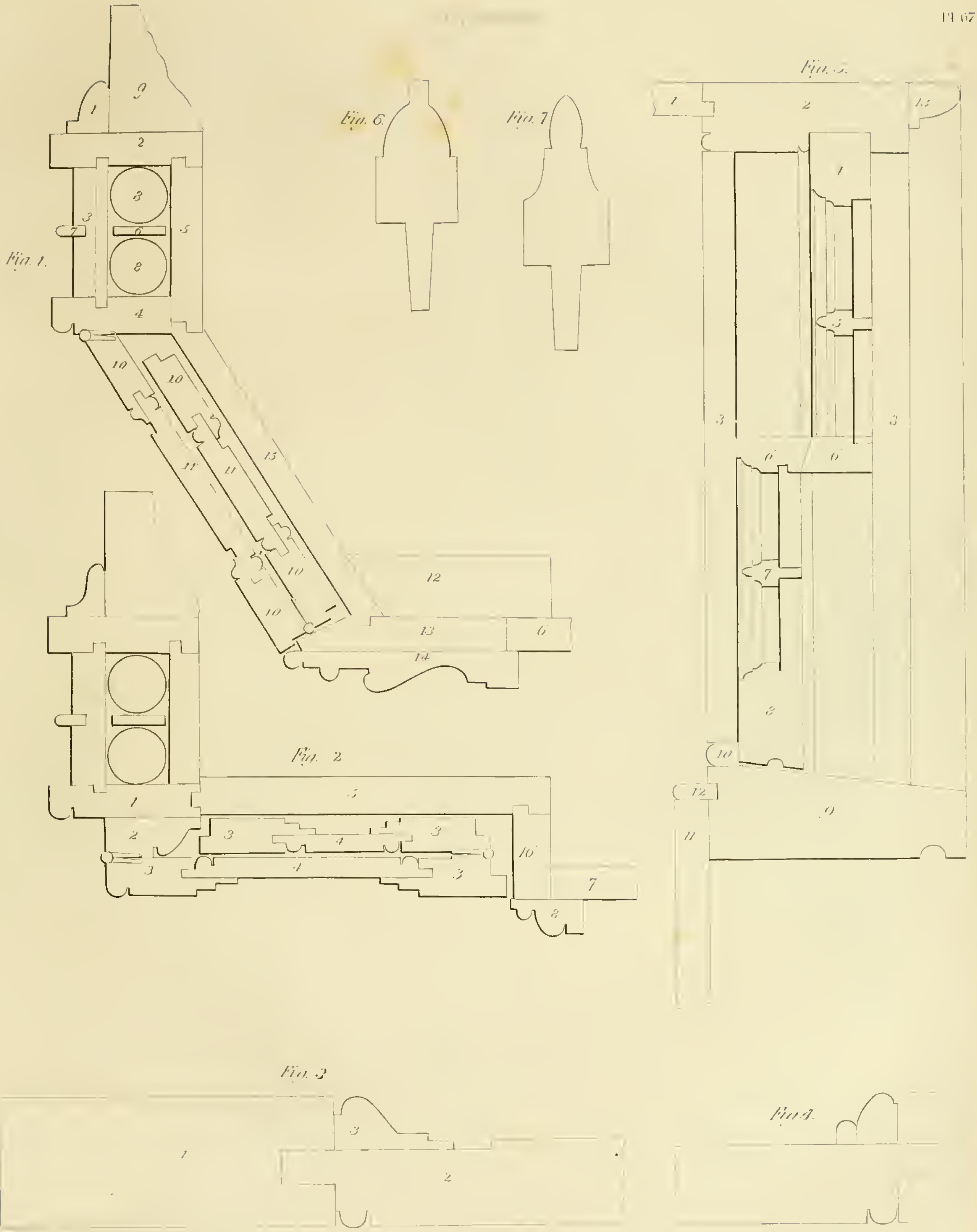
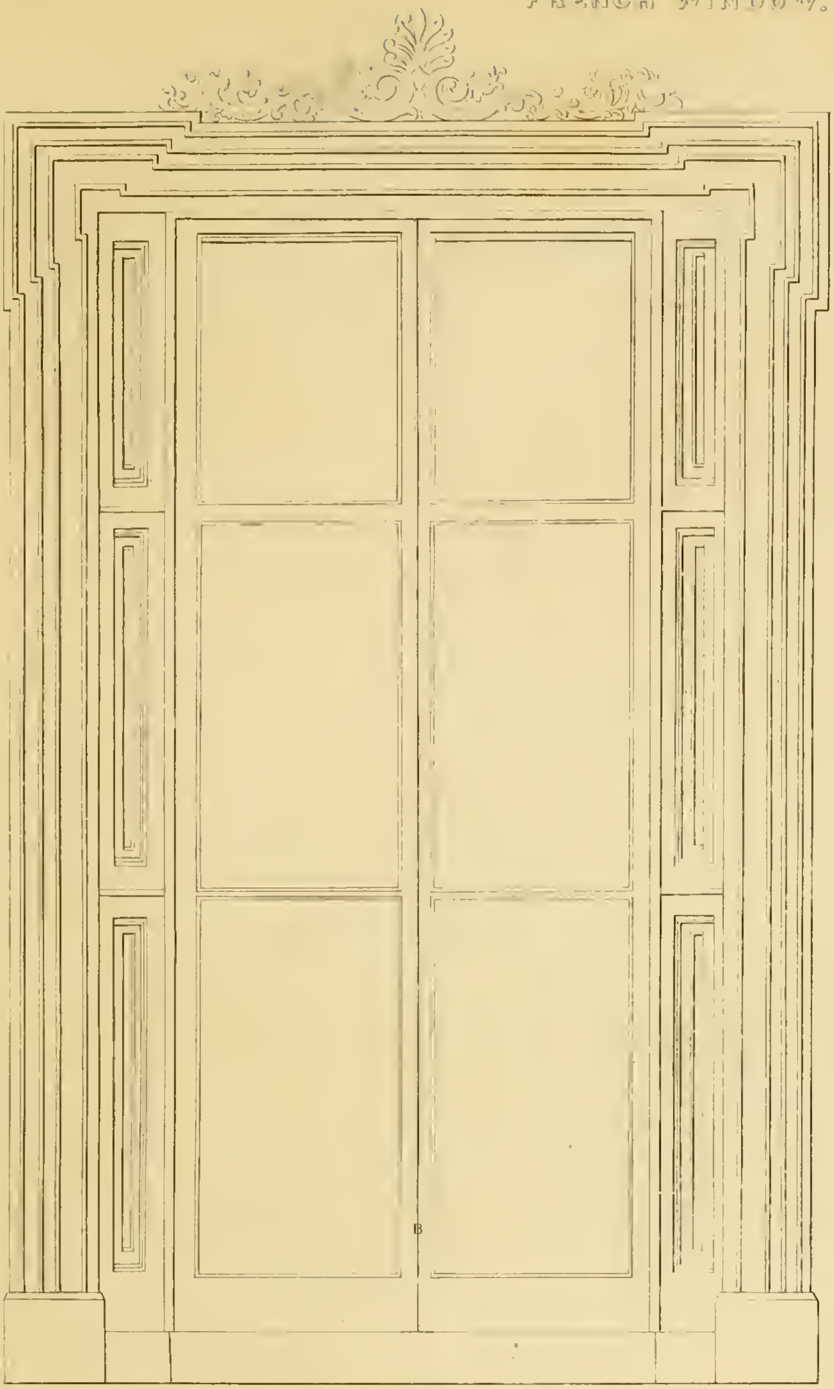


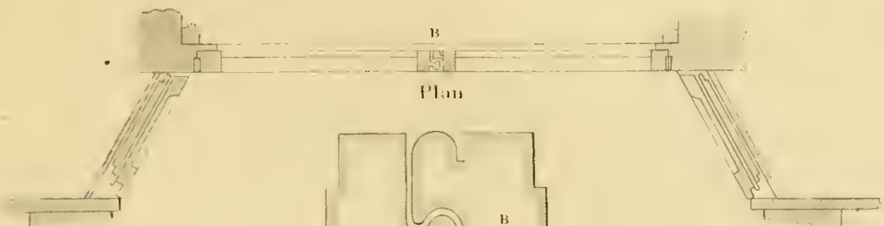
Fig. 1.
Fig. 2
Fig. 3
Fig. 4.
Fig. 5.
Fig. 6.
Fig. 7

FRENCH WINDOW.



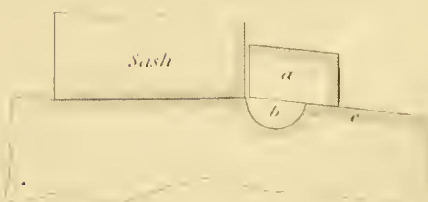
Elevation

Section.



Plan

Style at B



Scale

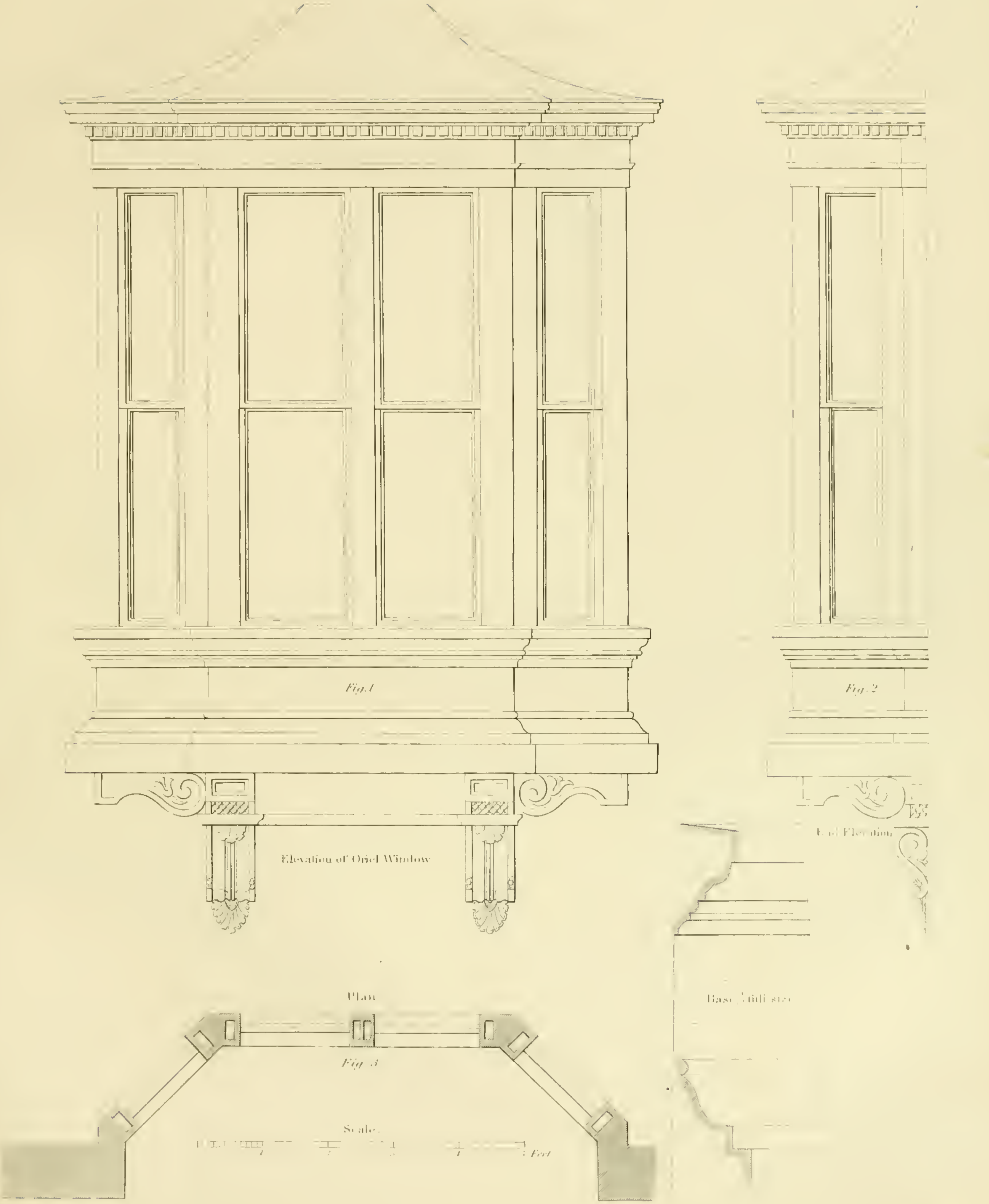
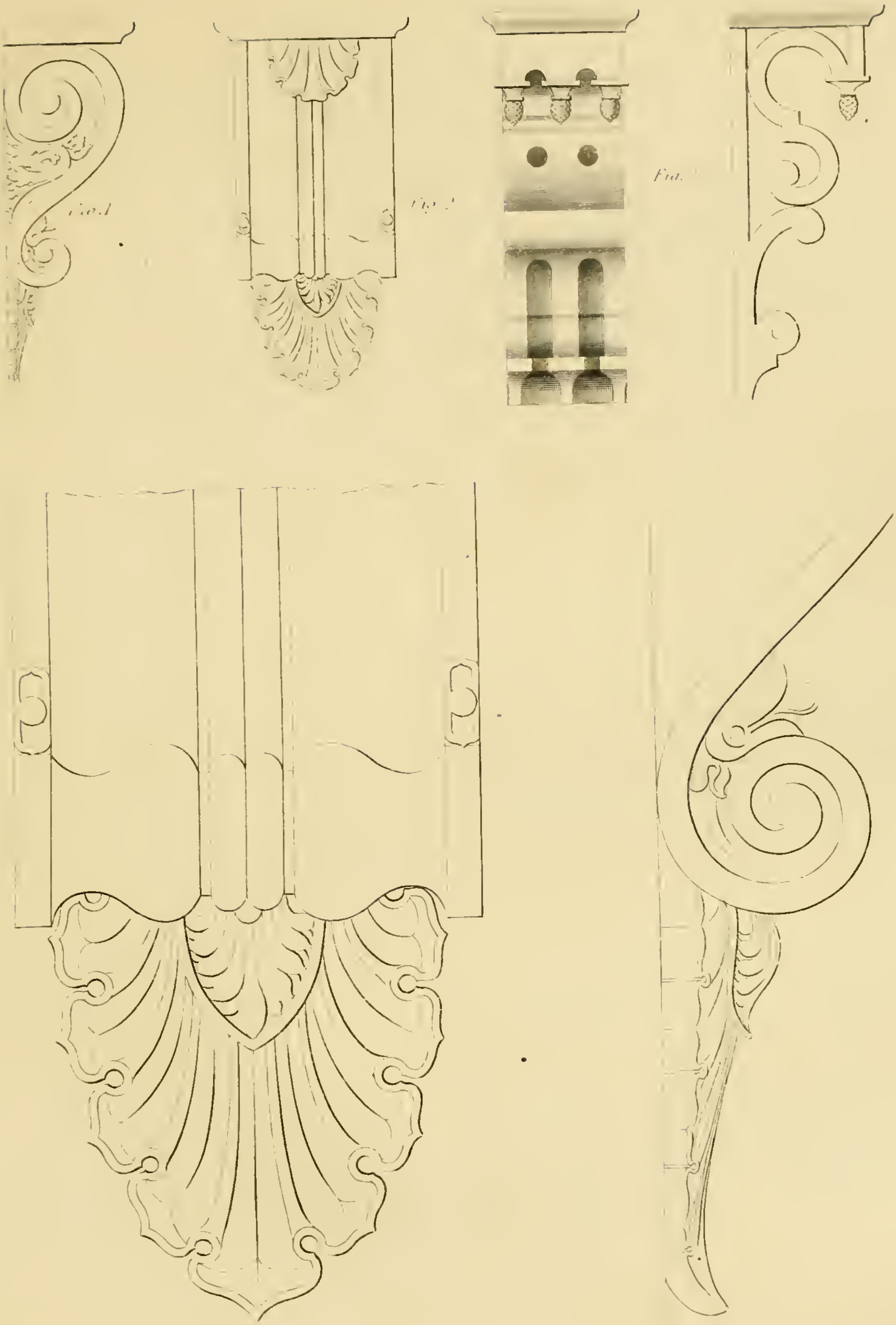


Fig. 1
Fig. 2
End Elevation
Elevation of Oriel Window
Base, full size
Plan
Fig. 3
Scale.
1
2
3
4
5 Feet

TRUSSES AND CONSOLES.



FOLIAGE.

Both the elements and composition of foliage are here considered, and illustrated by plates. The examples are taken from the remains of the most esteemed buildings of Grecian and Roman antiquity. The learner is recommended to go through all the variety of ornaments exhibited in this department, by which means he will be enabled to apply himself to any other species, however different.

DEFINITIONS.

1. An artificial arrangement or disposition of leaves is called *foliage.*

2. The subdivisions of single leaves are called *raffles.* The leaves which are chiefly used in architecture are the acanthus, olive, parsley, laurel, and lotus.

3. An artificial arrangement of leaves, branches, fruit, flowers, drapery, &c., either singly or combined in any manner with each other, are called *ornaments* in architecture.

4. A string, consisting of flowers, fruit, leaves, and branches, either singly or intermixed with each other, and supported at the two extremes, the middle part forming itself into a curve by its gravity, is called a *festoon.*

5. A curve line, which is continually changing its position in contrary directions on the same side of it,—that is, first concave and then convex, concave again and then convex again, and so on alternately, in this manner, to any number of curves of contrary flexure, — is called a *serpentine line.*

6. If from a stalk, in the form of a serpentine line, a number of branches issue out, twisting themselves in the form of spiral lines, on each side of the serpentine, in all the concave parts on the alternate sides of it, and if these spirals and the stalk be decorated with foliage,—a composition so formed is called *winding foliage.*

TO DRAW ORNAMENTS.

PROBLEM.

The learner should, in the first place, draw a great variety of curve and spiral lines of different descriptions, and compare these figures with each other, by which means he will be able at sight to distinguish each particular species of curve from another; then he ought to endeavor to imitate, with precision, the same things by hand in every variety of position which he can suggest to himself, and hence he will acquire a freedom of hand in every direction. When he proceeds to copying leaves, a general outline ought to be drawn, circumscribing the whole leaf; he should then form outlines of all the raffles, and round every compartment, circumscribing all the different sets of points or raffles, and afterwards proceed to draw the raffles themselves.

The learner having after sufficient practice in copying acquired a freedom of hand, he is advised to draw from nature a variety of such things as will be most suitable for the purposes to which they are to be applied. By so doing, the parts of his compositions will always appear rich and natural, and hence he will obtain a greater facility of invention. Having had sufficient practice in drawing from nature, he may then apply himself to the designing of ornaments; for which purpose he will find the first part of the problem, viz., that of drawing curve and spiral lines by hand, to be of the utmost utility in forming the general outline of his design; and for finishing the smaller parts, such as raffles, flowers, fruit, &c., he must apply the knowledge he has acquired in drawing from nature, which will complete his composition.

LEAVES.

Of the acanthus, bear's breech, or brank ursine, there are several species.

1. The mollis, or common bear's breech, a native of Italy.

2. The spinosus, or prickly bear's breech, the leaves of which are deeply jagged in very regular order, and each segment is terminated with a sharp spine, as is also the complement of the flower, which render it troublesome to handle them.

3. The ilietfolious, or shrubby bear's breech, grows in both the Indies. It is an evergreen shrub, which rises about four feet high, and is divided into many branches, garnished with leaves like those of the common holly, and armed with spines in the same manner; the flowers are white, and shaped like those of the common acanthus, but smaller.

4. The nigra, or Portugal bear's breech, with smooth sinuated leaves, of a livid green color.

5. The middle bear's breech, with entire leaves, having spines on their borders.

EXAMPLE.

Plate 71

Shows the method of beginning to draw leaves, as given in the general problem 1.

Suppose it were required to draw or copy plate 72, either of the same size, or in any other ratio to it. First inspect plate 72, and draw with a pencil a faint curve line, circumscribing the contour or general outline of Fig. 1; then describe curve lines similar to it, as at Fig. 1, plate 71; then draw lines faintly with a pencil, circumscribing the compartments or divisions of Fig. 1, plate 72; then draw lines in a similar manner, as at Fig. 1, plate 71, observing that all the parts are similar to Fig. 1, plate 72; next draw the raffles and veins in the compartments of Fig. 1, plate 71; and, lastly, with a pen draw in ink all the parts of the leaf represented by Fig. 1, plate 72; then rub your drawing clean; the pencil lines will be rubbed out, and the ink lines will be left, and will represent a figure similar to Fig. 1, plate 72.

This explanation will be sufficient for all the following examples, however dissimilar they may be. In the following descriptions, it will be only necessary to mention the names of the buildings from which the examples were taken.

Plate 72.

Fig. 1 is taken from the Arch of Adrian, at Athens.

No. 1. The profile of Fig. 1.

Fig. 2. From the Monument of Lysicrates at Athens, commonly called the Lantern of Demosthenes.

No. 2. Profile of ditto.

Plate 73.

Fig. 1. From the Temple of Pola, in Istria.

No. 1. Profile of ditto.

Fig. 2. From the Arch of Adrian, at Athens.

No. 2. A profile of ditto.

Fig. 3. Elevation of a leaf taken from the capitals of the columns on the Baths of the Diocletian, at Rome.

No. 3. Profile of ditto.

ROSES IN THE CAPITALS OF COLUMNS.

Plate 74.

Fig. 1. Elevation of the rose in the abacus in the Temple of Vesta, at Tivoli.

Fig. 2. The elevation of a rose taken from the Temple of Jupiter the Thunderer, at Rome.

Fig. 3. Elevation of a rose from the abacus of the capitals of the Temple of Vesta, at Rome.

Fig. 4. Elevation of a rose in the abacus of the capitals of the pilasters of the frontispiece of Nero, at Rome.

Plate 75.

Fig. 1. Elevation of a rose in the abacus of the capitals of the Arch of Titus, at Rome.

Fig. A. Elevation of a rose in the abacus of the capitals of the Pantheon, at Rome.

Figs. 2 and 3 are designs for the ornaments of modillions in cornices or corner pieces for pilasters.

Plate 76.

Fig. 1, the outline; and Fig. 2, the shadowed leaf taken from a frontispiece.

Plate 77.

Fig. 1. From the portico of the Temple of Antoninus and Faustina, at Rome.

Figs. 2, 3, and 4. For corners and centres of panels.

ORNAMENTS FOR MOULDINGS.

Plate 78.

No. 1. A general outline of Example 1.

No. 2. The outline of Example 2, from the cimatium of the Temple of Minerva Polias, at Priene.

Example 3. From the cima recta in the cornice of the Temple of Bacchus, at Teos.

N.º 1

Fig. 1.

N.º 2

Fig. 2.

Fig. 1.

N° 1.

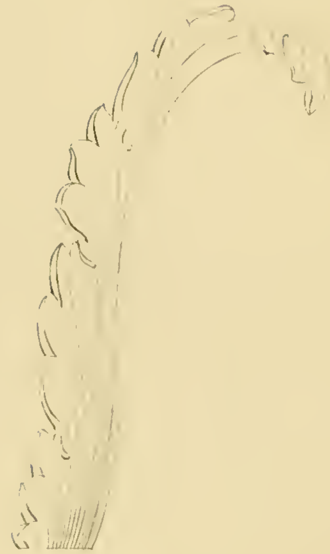
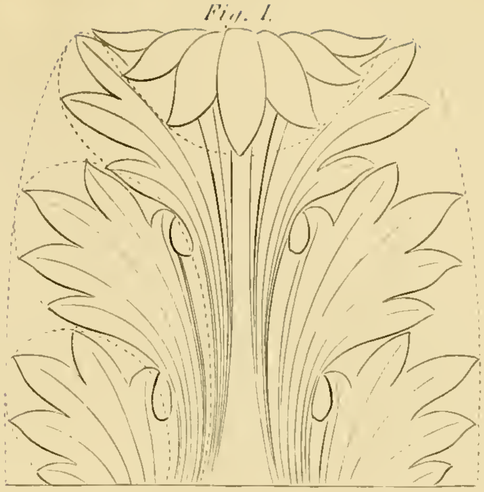


Fig. 2.

N° 2.

No. 1.

Fig. 1.

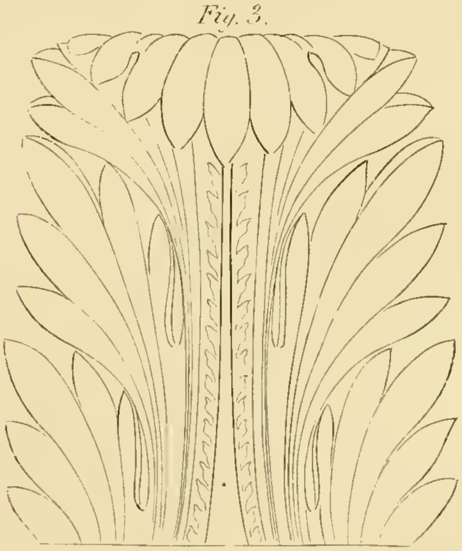


No. 2.

Fig. 2.

No. 3.

Fig. 3.



N° 1

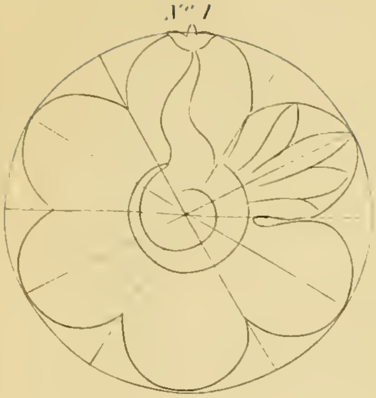


Fig. 2

N° 2

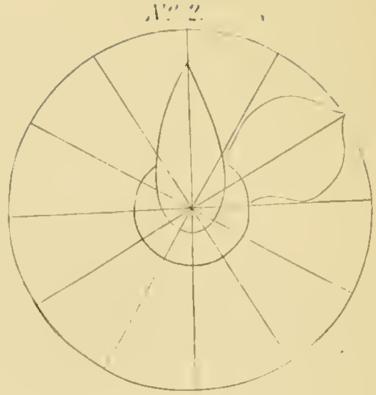
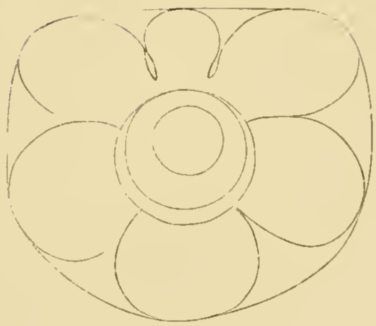
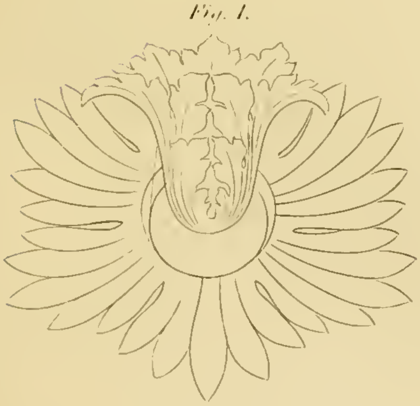


Fig. 1



N° 3

Fig. 1.



N° 1

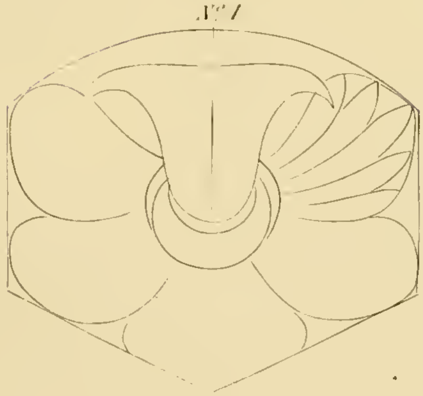


Fig. 3.

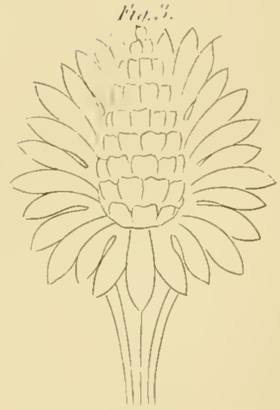


Fig. 1.

N° 1.

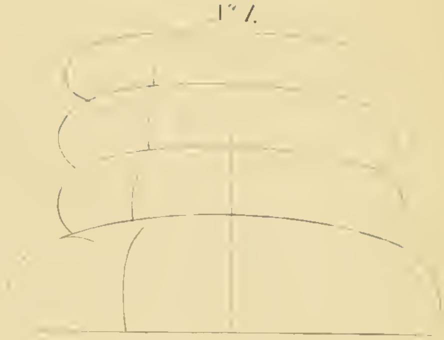
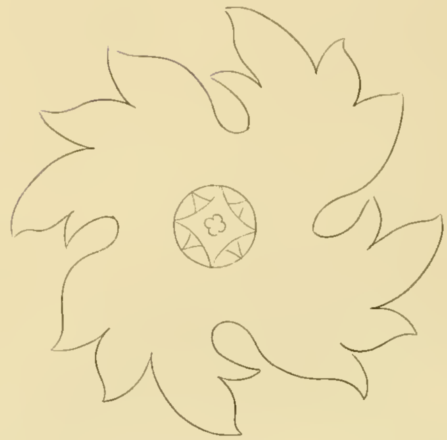


Fig. 2.

N° 2.



N° 3.

Fig. 3.

Fig. 1.

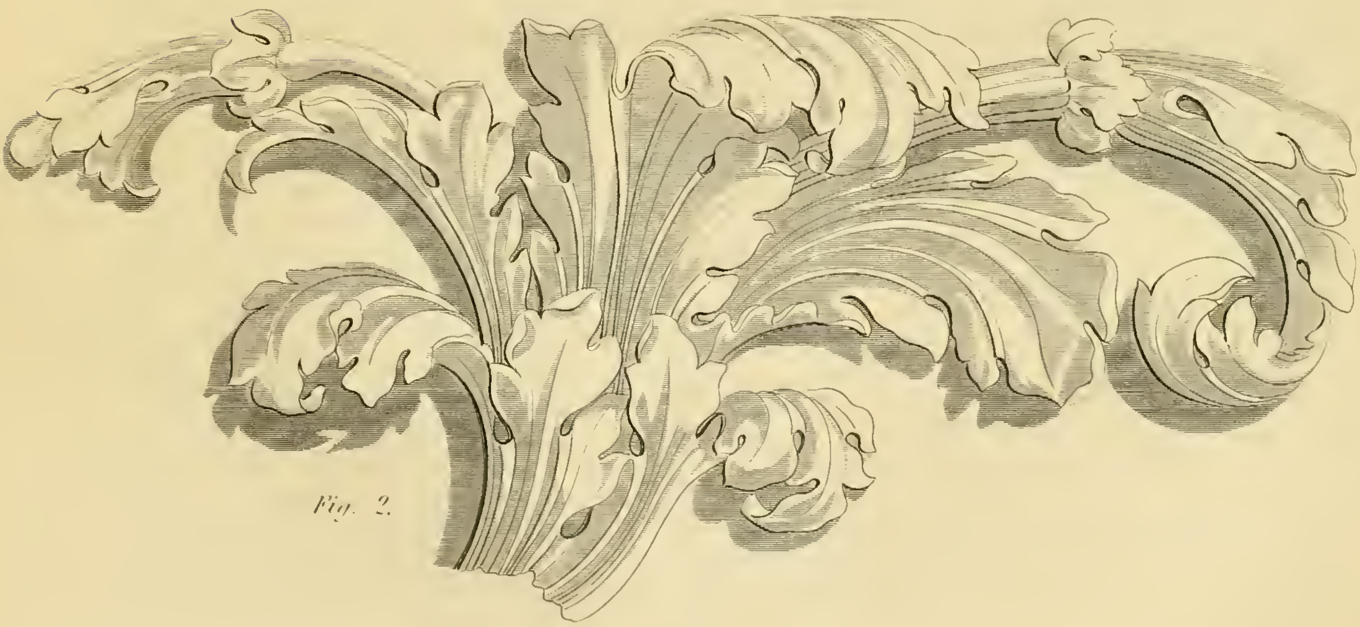


Fig. 2.

Fig. 1.

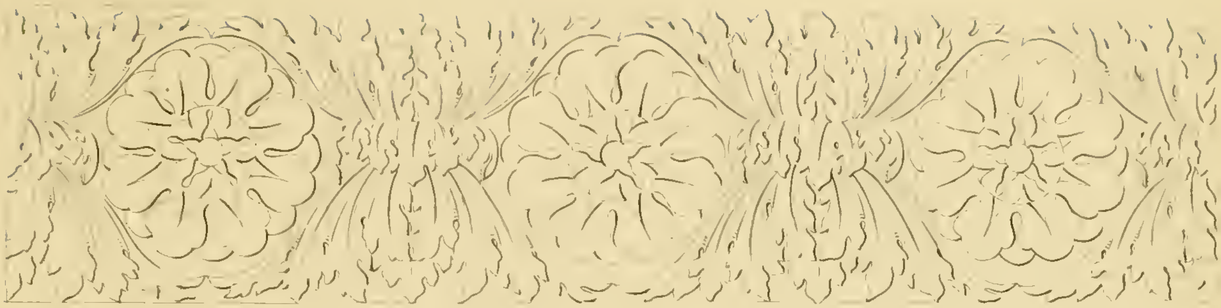
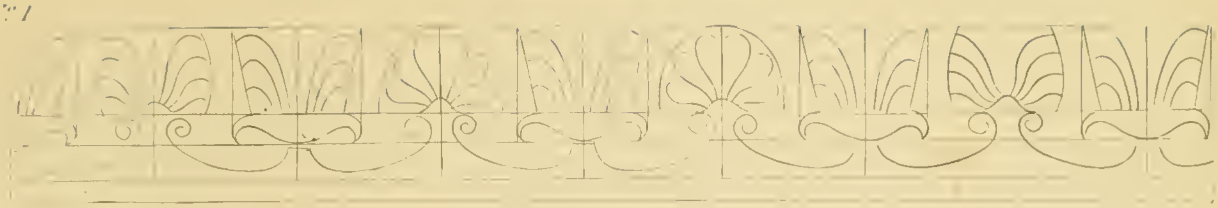


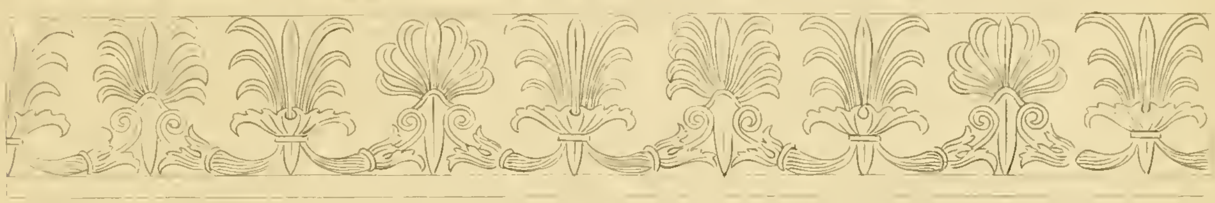
Fig. 2.

Fig. 3.

Nº 1



Example 1



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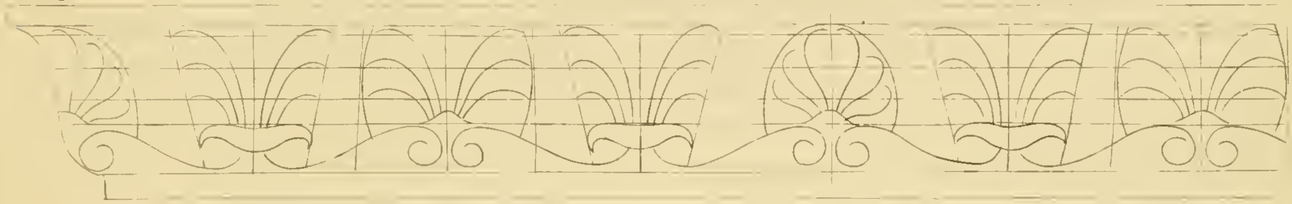


Example 2

Example 3

Example 4.

Fig 1.

Fig 2.

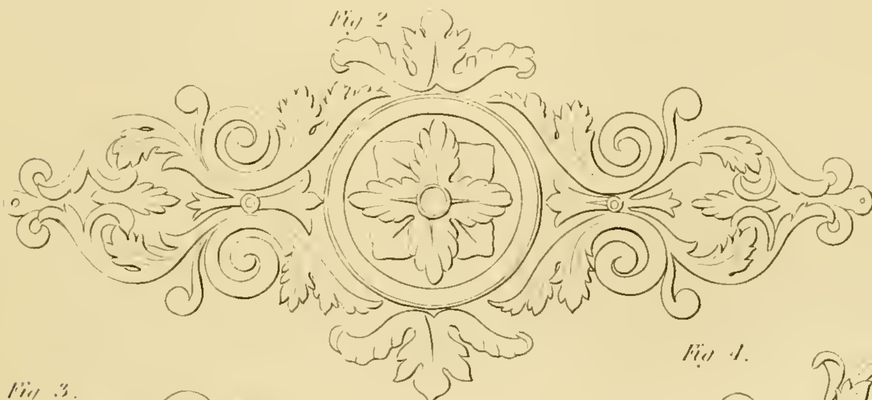


Fig 3.

Fig 4.

Fig. 1.

Fig. 2.

Fig. 3

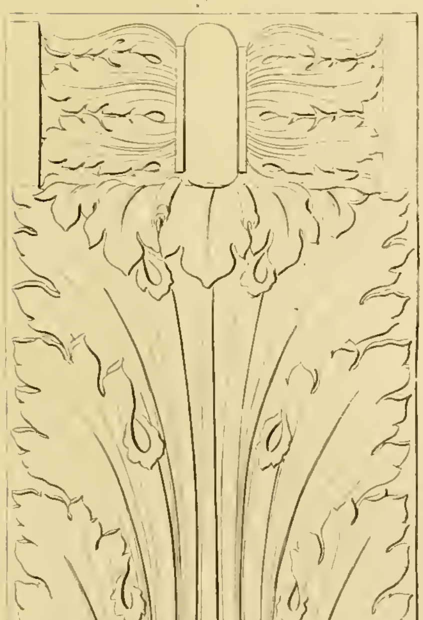
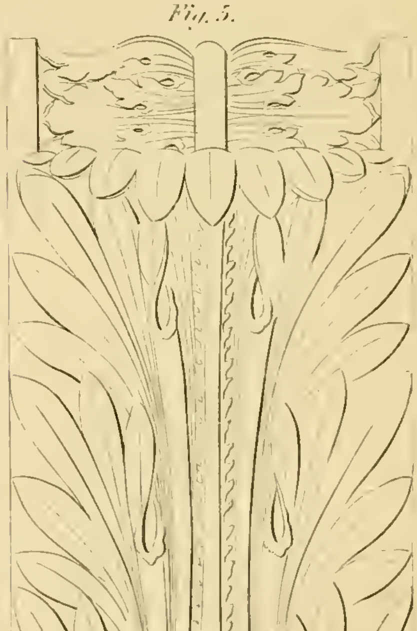


Fig. 4.

Fig. 5.



Example 4. From the cima recta of the cornice of the Temple of Peace, at Rome.

Plate 79.

Fig. 1. From the Arch of Titus, at Rome.

Fig. 2. From an impost moulding in the Arch of Septimius Severus, at Rome.

Fig. 3. From the cima recta of the cornice of the Frontispiece of Nero, at Rome.

Plate 80.

Fig. 1. The side, and Fig. 2, the front, of a key-stone of the Arch of Septimius Severus, at Rome.

Fig. 3. The ichnography of the modillion in the cornice of the Temple of Jupiter Stator, at Rome.

Fig. 4. Side of the modillion in the cornice of the Portico of the Pantheon, at Rome.

Fig. 5. Ichnography of ditto, inverted.

CARPENTRY.

The art of Carpentry, in the general acceptation of the term, includes every method of working or employing timber, or its substitutes, in the construction of buildings; but as it is evident that coarse, rough work requires very different management from the delicate finish of interior arrangement, most writers have very properly divided it into two classes: *Carpentry*, properly so called, to which belongs flooring, roofing, framing, and the working of all large pieces of wood; and *Joinery*, which includes all ornamental works in wood, (except what are obviously within the province of the cabinet maker,) besides doors, windows, sashes, and other objects intended for close inspection. The former, of course, is treated of in this department.

THE ORDER OF CARRYING ON A BUILDING; THE DIMENSIONS OF THE TIMBERS; THEIR DISTANCES, AND PLACES OF INSERTION.

The designs of buildings being of such a variety, they not only require various methods of construction, but some require appendages which are unnecessary in others, and thus the order of proceeding will be varied. The order, however, of proceeding with any description of edifice will easily be understood, when that of the usual manner is given.

Lintellings very soon occur; their thickness ought never to be less than as many inches as the aperture has feet in width. Some recommend that lintels should be laid on templets; but when the mortar dries, this practice, though it may seem to bind a new building together, is injurious to the strength of the walls. The old authors say that bond timbers should be dovetailed at the angles; but this method of joining timbers is not sufficient to prevent, in two return walls, the one from descending, while the other keeps its place; halving and bolting is much more secure.

Where bond timbers are carried all round apartments or rooms, or entirely round a building, the thickness of these timbers will depend upon the mass of the work over them; but where they are only partially inserted for finishings, their thickness must be the thickness of a brick. Some old authors think it would not be amiss to place bond timbers at the distance of six feet through the whole height of the building; but, in our opinion, they ought to be used with great caution; for as the moisture dries out of the timber, these ligatures will shrink and cause the walls to bulge, which will not only produce a very unpleasant effect to the eye, but will endanger the building, by weakening the walls, and make them liable to fall. Therefore, in good work, bond timbers ought to be dispensed with; and, if necessary, other means ought to be resorted to, which will be equally effective in point of strength; but as neither stone nor iron will answer the purpose of fixing, we will recommend plugging, built in with the brick work.

FLOORS.

We now come to the consideration of floors. Instead of mortising the ceiling joists, we would rather recommend to notch them upon, and fasten them to, the binding joists by means of nails. In some single joisted floors, every third or fourth joist is made deeper than the intermediate joists, and the ceiling joists are fixed to the deep joists. This construction is adapted to the prevention of sound, by reason of the space which destroys or cuts off the conducting power.

As no timbers must enter a wall where there are fireplaces or flues, the ends of the joists, instead of being supported by the wall, must be supported by trimmers and trimming joists. As the trimming joists have to support the trimmers, and these again the ends of the joists, the trimming joists should be increased in their thickness about one fifth part more than the breadth of a common joist.

In double floors, the under sides of the binding joists are frequently framed flush with the under side of the girder, and about three or four inches below the top, in order to receive the bridging joists. Some old authors direct that the bridging joists should be pinned down to the binding joists; but this is unnecessary, and, besides, it weakens the binding joists; this method is therefore inadmissible. It was formerly the practice to place the binding joists about three feet or three feet six inches distant from each other; the mean distance of the present practice is about five feet. Single floors, consisting of the same quantity of timber, are much stronger than framed floors; but a preference is sometimes given to framed floors in superior buildings, on account that they are not so liable to fracture the ceilings, and because they conduct sound more imperfectly than a common joist floor; and hence it is that single floors can only be employed in inferior buildings. Framed floors differ from double floors only in the binding joists being framed to girders.

In single floors, where the joists exceed eight feet bearing, pieces of board ought to be inserted in the spaces between the joists, in a vertical position, and nearly the whole depth of the joists, and in one continued line at right angles to the joisting. The pieces of timber thus inserted are called *bridges*, and the floor is said to be *bridged;* the bridges ought not to be driven in with great force, but their ends should be in close contact with the vertical sides of the joists, and should be fixed thereto with a nail at each end.

The bridging of a floor is of great use, when the joists are thin and deep, in preventing their buckling by pressure; but for this purpose there is another method, called *keying*, which consists of framing short pieces of timber between the joists; but as the mortises which receive the tenons weaken the joists, and as the keys cannot be in a straight line, and since this method adds considerably to the expense, this practice is not so eligible as that of bridging. Single joist flooring may be used to any extent not exceeding sixteen feet: but when it is desirable to preserve the ceiling free from cracks, and prevent the passage of sound, a framed floor is necessary.

The ceiling joists in double floors are generally put in after the building is up; if, therefore, they are fixed by means of mortises in the sides of the binding joists, to receive the tenons on their ends, the space between every other two mortises must be grooved out alternately upon the opposite sides of the two adjacent binding joists: by this means, the ceiling joists may easily be put in their places, by inserting the tenons in each ceiling joist in the mortises at one end, and sliding the tenon on the other end along the groove in the arc of a circle, until the ceiling joist come at a right angle with the binding joist. The long mortises or grooves in the sides of the binding joists are called *chase mortises*, or *pulley mortises.* The ceiling joists may be thirteen or fourteen inches apart; the thickness of the bridging joists and ceiling joists need not be greater than what is sufficient to resist splitting by the driving in of the nails in order to fix them. It has been found, by experience, that two inches is a sufficient thickness for the purpose.

In double-framed floors, the distance of bridging joists, in the clear, ought to be about twelve inches, and should never exceed thirteen. It is a good practice to plane the upper edges of the bridging joists straight, because, when the boarding is laid, the faces for walking upon will be more regular than if the boards had been laid down upon the edges of the bridging joists when rough from the saw. The straightening of the edges of the bridging joists will not only give greater facility to the making of a level floor, but will contribute greatly towards making sound work, and will prevent that disagreeable creaking noise which arises from the parts not being brought into contact; for when the tops of the joists on which the flooring boards are laid are uneven, it will be impossible to avoid furring up the joists, or, what is still worse, inserting chips in the hollows, which will give way in the nailing of the boards to the joists. The general practice is to make binding joists half as thick again as common joists; so that, if a common joist be two inches thick, the binding joists may be three inches thick.

Girders should always be placed upon walls which are solid underneath; but when it becomes necessary to lay them over apertures, the lintels should be sufficiently strong to support them. We cannot recom-

mend the practice of laying girders obliquely across the room, since it divides the binding joists so very unequally.

All joists should be laid with a camber upwards, so as to raise the middle of the floor about three quarters of an inch higher than the sides of the room; and a similar observation applies to ceiling joists, viz., that the under horizontal sides should rise with a concavity, so that the middle of the ceiling should be three quarters of an inch above the margins at the cornices or walls. The distance of girders from each, or the walls, should never exceed twelve feet.

Girders should always be made of timber of the best quality that can be found, and particularly those which have long bearings. When the bearing exceeds twenty feet, it is difficult to procure timber of sufficient dimensions; and the only method is to allow a sufficient thickness between the surface of the boarding and the ceiling, since it is found, by experiments that have been made, that a truss girder is not even so strong as a solid beam of the same depth. The reason is obvious, for braces which have only a small inclination to the horizon throw the most enormous compression on their abutments, which is liable to give way, and the effect of trussing would be rendered useless; but if a sufficient height were allowed for trussing, girders might be made capable of supporting any weight whatever. Two feet, or even three feet, in the height of a building, would be an ample allowance for framing girders of sufficient strength, and would not occasion any considerable expense to the structure, but would give solidity to the walls, by having a greater distance between the apertures. But where the depth is limited, and the bearing considerable, girders ought to be made solid, and of cast iron. In order to equalize the strength of solid girders, builders frequently cut them longitudinally along the middle, and turn the ends of the flitches contrary to what they were at first in the solid, and apply the sawn sides so as to face each other, and then bolt the two pieces together in a sufficient number of intervals; but it is evident that, since the holes made for the passing of the bolts will weaken the timber, very little strength will be gained. This process, however, affords the opportunity of examining the timber, as, in large trees, the heart is frequently found in a state of decay. When this process of reversing and bolting is used, the two sawn sides of the timber should not be brought in contact, but should be separated by parallel pieces of wood, so as to allow a sufficient circulation of air to pass between the two sides of the flitches of the beams thus bolted.

To prevent the sagging of short girders, it is usual to cut them camber; that is, to cut them with an angle in the middle of their lengths, so that their centres shall rise above the level of their ends as many half inches as the girder contains ten feet lengths. And, indeed, girders of the greatest length, although trussed, should be cut crowning in the same manner.

It may be proper here to notice, that the cambering of girders does not prevent them from sagging, though perhaps it may obviate their becoming concave on the upper side. With regard to trussing girders, the flitches should not be cut to a camber, but brought into this state in the act of trussing.

PARTITIONS.

Partitions are usually lathed and plastered; and sometimes the spaces between the timbers are filled with brick work. A partition ought to be so constructed as to be capable of supporting its own weight, in whatever situation the door is placed, or whether there is a door in the middle, or two doors near the ends. Partitions that rest upon a solid wall do not require trussing; but when there is no support, except at the ends, or at two given fixed points, the braces ought to be so disposed as to discharge the weight of the whole mass upon these points; and it is better to support a partition by the extreme walls it is connected with than upon any solid from the bottom; for, in the settlement of the walls, the partitions will be carried along with them; but if supported from the ground by light materials, the walls and partitions will descend unequally, and cause large fissures and cracks in the ceilings and in the plaster upon the walls and partitions.

When a partition is supported at each end by walls of unequal heights, the wall, which is the most ponderous, will sink in a much greater degree than that which is the lighter; therefore, in this case, whatever care may be taken with the framing of the partitions, it will not be possible to avoid the cracking and splitting of the plaster upon the walls and ceiling. Such consequences should be guarded against in the design of the architect.

FRAMING.

This mechanical science is divided into two principles — the Scribe and the Square Rule.

THE SCRIBE RULE.

1. *First*, the mortises should be made, and the faces got out of wind. *Second*, after finding the length of the timber in which the tenons are to be made, for convenience apply the two-foot square. *Third*, take out the size of the mortised timber on the end of the square; suppose ten inches to be the one mortised, then fourteen inches remain on the square; make a distinct mark at the end of the square, which is called the two-feet mark. *Fourth*, measure from this mark, for the shoulder, fifteen inches, which leaves one inch to be scribed; after the tenon is made and entered, the mortise and the shoulders are brought together or to a bearing; then cut the shoulders to the scribe, and when put together they will remain out of wind, as when scribed. The process is generally applied to sills, posts, and principal rafters.

2. A process called *tumbling*, is applied to timbers, both ends of which are to be tenoned, as girders, &c.; also to sides and ends in section framing.

The girder should be placed so that both ends shall come directly over the lower end of the mortises. For the tenons you are about to strike, place the lower edges of the girder to the line of the lower end of the mortises; make a scratch on the girder at both ends, exactly to the face of the mortise. Cant the girder so as to leave those marks up; fetch the girder again over the mortise, and apply the edge of the square to the face of the mortise, the square extending above the girder. Move the girder by a hammer for that purpose, until the scratch on the corner of the girder is brought to the outer edge of the square. Then with your compasses draw a line across the girder by the edge of the square; then move the square on the opposite side of the girder, and draw another line; in the same manner draw lines at the other end of the girder. Strike a line across the top and bottom of the girder, meeting the end of those which give the exact length of the shoulders; then strike the tenons.

3. Cant or plumb marks are those which are applied to all principal timbers that are to be employed in section framing, after having been put together in the sides. At some part of the post try on the square, and fit that part (which may be up, in the laying out of the section) to a right angle with the level plane of the side framing, provided the section should be at right angles with the sides. But if the section should be required at any other angle with the side, the plumb should be made according to that angle. The angle should be taken with a bevel set for that purpose; and on these fittings of the posts a right angle should be struck, to guide the direction of the square across the section framing. The posts should be brought by means of wedges in a horizontal plane across the section.

THE SQUARE RULE.

This principle is considered more simple than the Scribe Rule, as it can be applied in many cases with less help and more convenience.

In order to make a good frame of any considerable magnitude, it should be the first care of the master workman (after examining the plan of the frame with care) to make out a proper schedule of the various sizes of the timber. Set down their appropriate marks on the schedule; and when you have finished Nos. 1, 2, &c., check them on the schedule. It is of importance that all mortises, tenons, pin holes, &c., should be struck with a pattern. All the timber should be lined to its proper size, and the mortises faced to the same. Care should be taken in applying the pattern; for striking, it should be governed by the appropriate lines. This method has the preference in detached framing; the timber admitting of being framed in different places, and not tried together until its raising.

TRUSSES.

Plate 81.

Fig. 1 represents a truss partition. *a*, the truss plate. *b*, the sill. *c c*, the posts. *d*, the truss beam. *e c*, the struts. *f f*, the studding. *g g*, the bridging. *h h h*, the door frames.

Fig. 2. Design for a truss gallery or floor.

Fig. 3. Method of scarfing and splicing timber.

Fig. 4. The horizontal section of Fig. 5.

Figs. 5 and 6 show the best method of trussing girders.

The king bolts through Figs. 5 and 6 show the two sides which incline to each other so as to form a wedge, and thereby force the trusses upon their abutments.

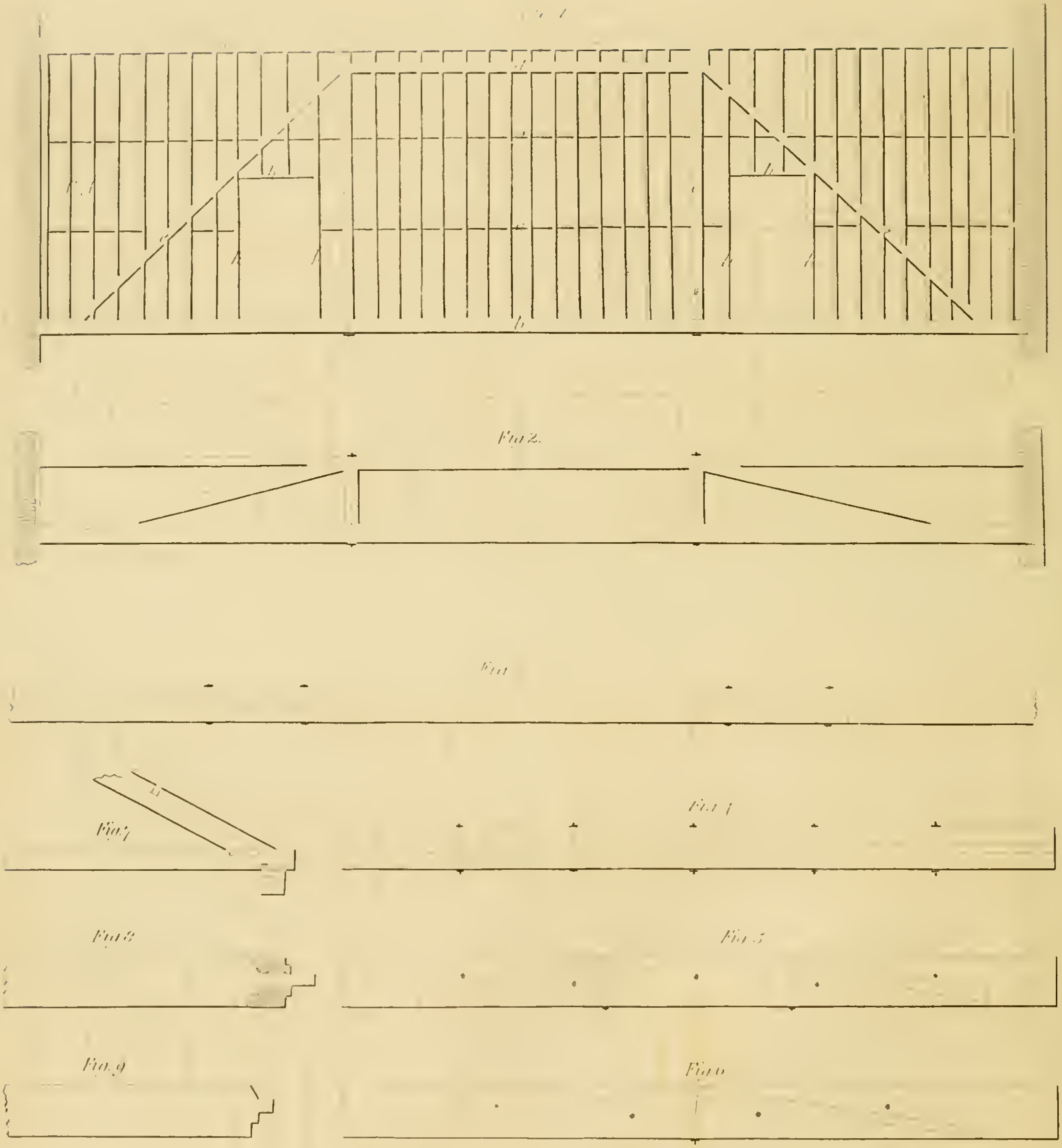


Fig. 2.
Fig. 7
Fig. 9

Fig. 2.

Fig. 1.

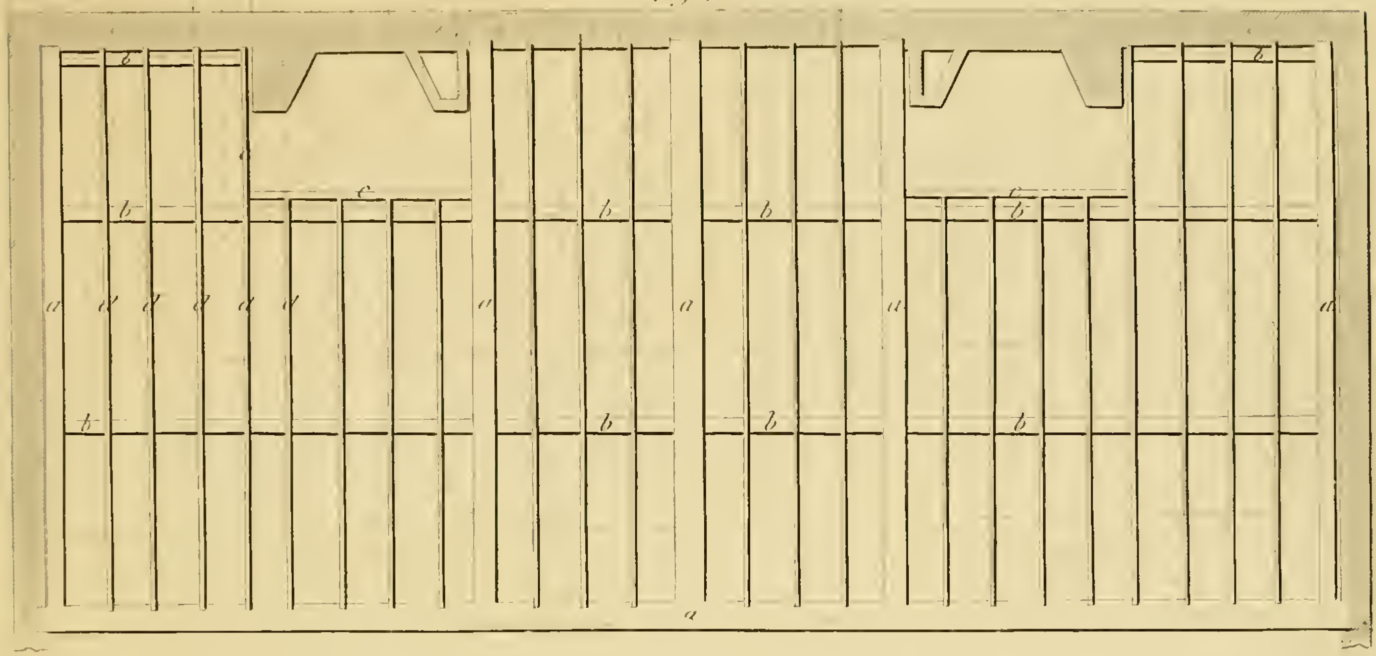


Fig. 3.

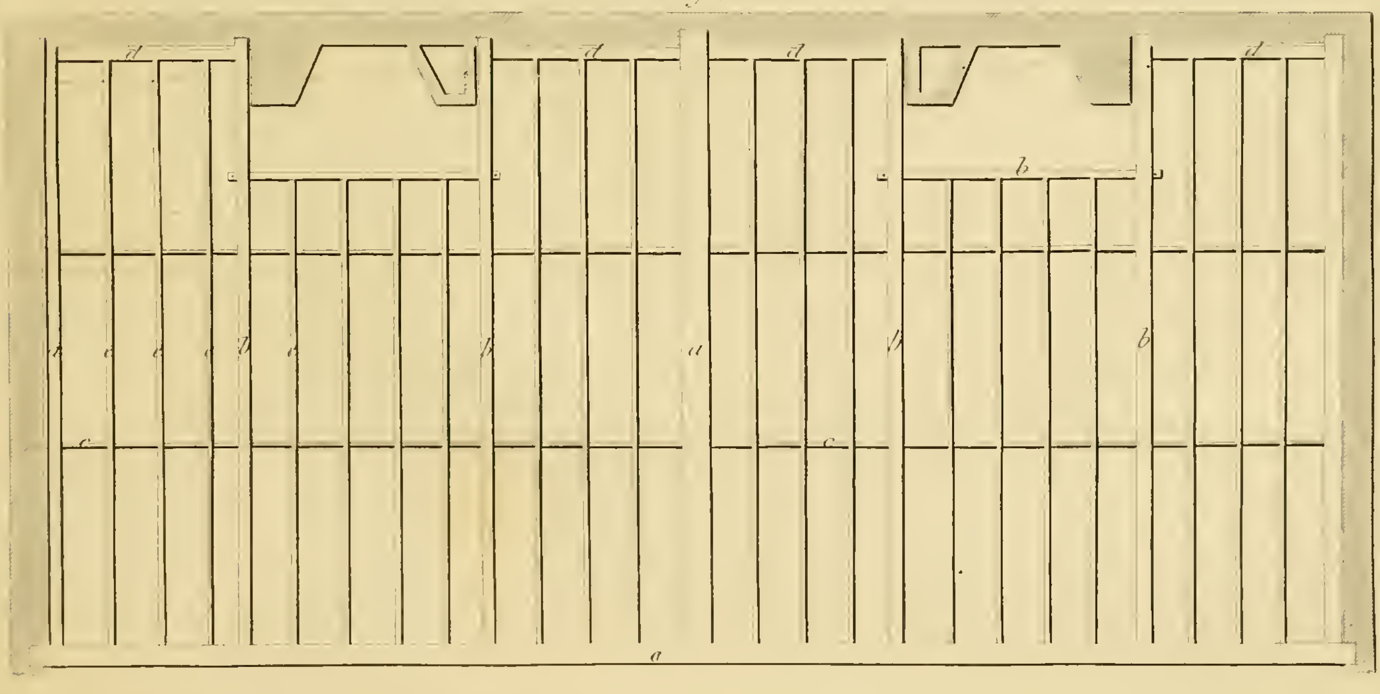


Fig. 1

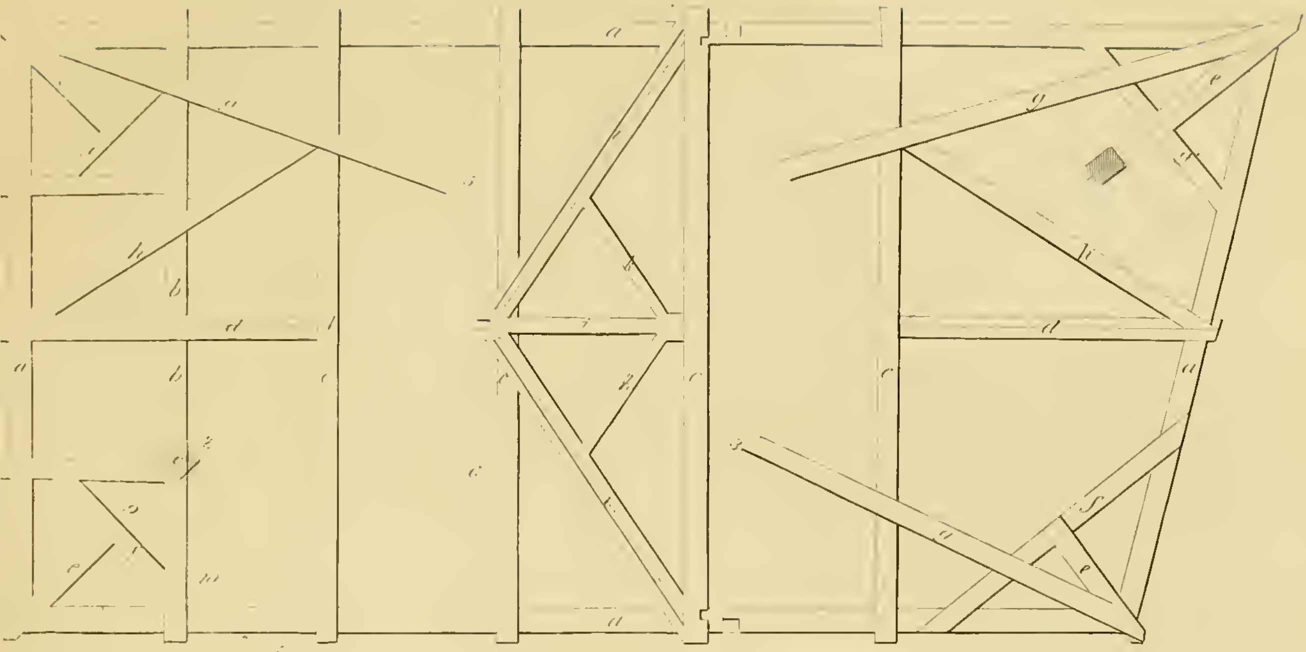


Fig. 2.

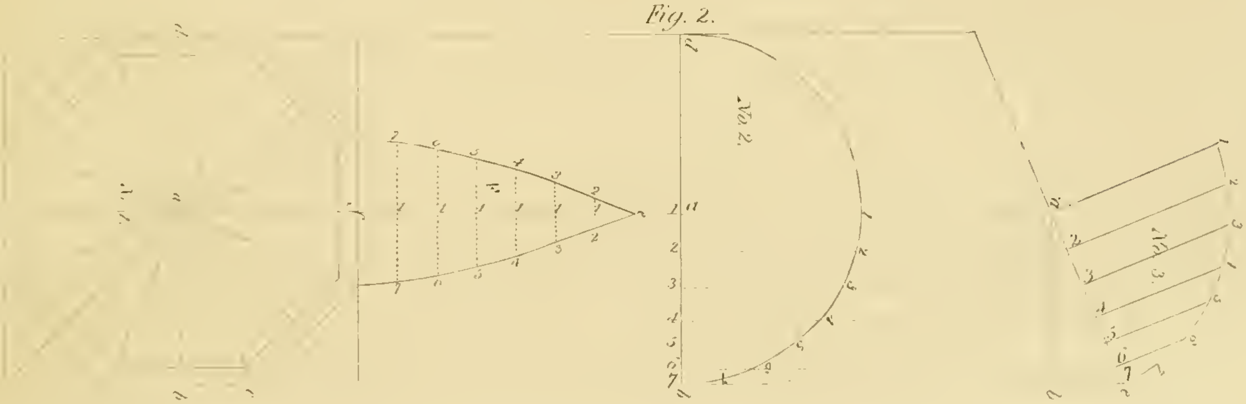
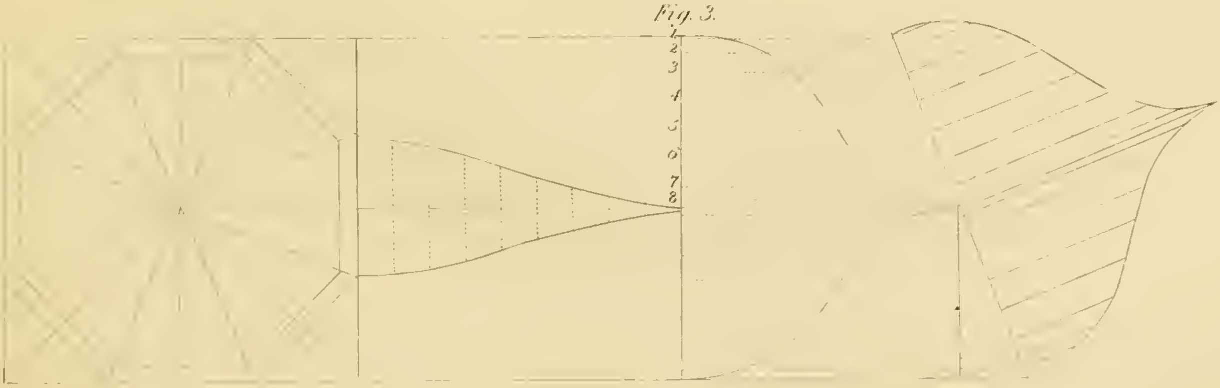


Fig. 3.



To lighten the Girders.

Having grooved the sides of the flitches for the trussing pieces, so as only to be close at the ends, about an inch and a half deep on each side, and having greased the head of the king bolt, and put the whole slackly together sideways by the screws, proceed then to turn the nut of the king bolt, and let another person strike the head with a mallet; the stroke will make the king bolt start every time it is hit, and give fresh ease for the turning of the nut. By this means, the girder may be cambered or crowned at pleasure: the deflection from the straight line is generally one inch in twenty feet.

Fig. 7 shows the manner of joining the beam to the wall plate.

Fig. 8. The manner of keying the tenon through the girder.

Fig. 9. Profile of the tusk tenon.

PLANS OF FLOORS.

Plate 82.

Fig. 1. Plan of the floor, suitable for buildings of any magnitude.

a a a a a, girders resting upon the walls. *b b b b*, binding joists. *c c c*, trimmers. *d d d d d*, bridging joists.

Fig. 2. Section of the floor.

Fig. 3 shows the method of framing floors with plank or deep joists.

a, the girder resting upon the walls, and should be 10 by 12 inches. *b b b b*, trimmer joist, 4 by 12 inches. *e e e*, joist. *d d d d*, wall girders, 6 by 12 inches. *c c c*, bridging joist, 2 by 12 inches.

This floor is adapted to rooms 16 or 18 feet square, and the size of the joist should be 12 inches by $2\frac{1}{2}$ or 3 inches.

DESIGNS FOR ROOFS.

A roof, in architecture, is a cover of a building for protecting its inhabitants from disagreeable changes of weather, and from the depredations of evil-disposed persons; but a roof in carpentry is the timber framing made to support the actual covering of boards, shingles, slate, lead, &c. As the roof may be made one of the principal ties of a building, it should not be made too heavy to burden the walls, nor too light to be incapable of keeping them together.

The principal timbers of a roof are the wall plates, tie beams, principal rafters, common rafters, pole plates, purlines, king posts, queen posts, struts, straining beams, strong sills, &c. Hence, since the pressure of the roof is wholly discharged upon the wall plates, these should be made of sufficient thickness and breadth to distribute the weight of the roof to the best advantage.

Plate 83.

Fig. 1, *a a a a*, wall plate; *b b*, jack beams; *c c c c*, tie beams; *d d*, ridge line and jack beam; *e e e e*, dragon piece; *f f f f*, angle tie; *g g g*, hip rafters; *h h*, jack rafters; *i i*, principal rafters; *j*, king post; *k k*, strut braces.

To find the length and backing of hip rafters.

Draw 7, 4, 8, the base lines; then draw 4, 5, at right angles with 8, 4, which will give the perpendicular height of the backing of the hip rafter. From 9, extend one foot of the dividers to 10; describe the arc, cutting the base line at 2; then the lines from 2 to 1 and from 2 to 3 give the angle required for the backing. *c*, a section of the hip rafter.

To find the angle and intermediate ribs of octagon roofs.

Fig. 2 is the plan of an octagon dome, *a b* being the base line of the given rib. No. 2 shows the curve of the dome, in this case half of a circle drawn from the centre *a*. Draw *a* 1, cutting the circle at 1 and at right angles with *d b*, and produce it to *a;* divide *b* 1 into seven or more equal parts. Make *a b* No. 3 parallel and equal to *a b* No. 1, *b e* equal to *b c* No. 1, and draw *e a*. Then draw ordinates from *a b* No. 2 to *a e* No. 3, parallel to *a* 1, cutting the circle in No. 2 at 2, 3, 4, 5, 6, 7, and *a e* No. 3 at 2, 3, 4, 5, 6, 7. Draw *a* 1 at right angles with *a e*, also 2 2, 3 3, 4 4, 5 5, 6 6, and 7 7, parallel to *a* 1, and equal to 7 7, 6 6, 5 5, 4 4, 3 3, 2 2, and *a* 1 in No. 2, and then trace the curve *c* 7 6 5 4 3 2 and 1, which will, when placed in its right position, correspond with the given circle.

To find the form of a board to bend upright to the crown.

Fig. 2. Produce the line $a\ f$ to e No. 1. Take the divisions 2 3 4 5 6 7 on the curve line b 1 No. 2, and lay them from f in F along the line 1 1 1 1, &c., to e; then the line $f\ e$ No. 1 will be equal to the curve line b 1 No. 2. Transfer the ordinates 2 3 4 5 6 7 in the angle $a\ b\ e$ No. 3, and lay them from f in F No. 1 along the line 1 1 1 1, &c., at right angles with the line $f\ e$, and set them off on each side to 1 7, 1 7, 1 6, 1 6, 1 5, 1 5, 1 4, 1 4, 1 3, 1 3, and 1 2, 1 2.

Those, when traced, will give the form of the board F.

Fig. 3. An octagon roof of a different curvature from that represented in Fig. 2, but is formed on the same principles.

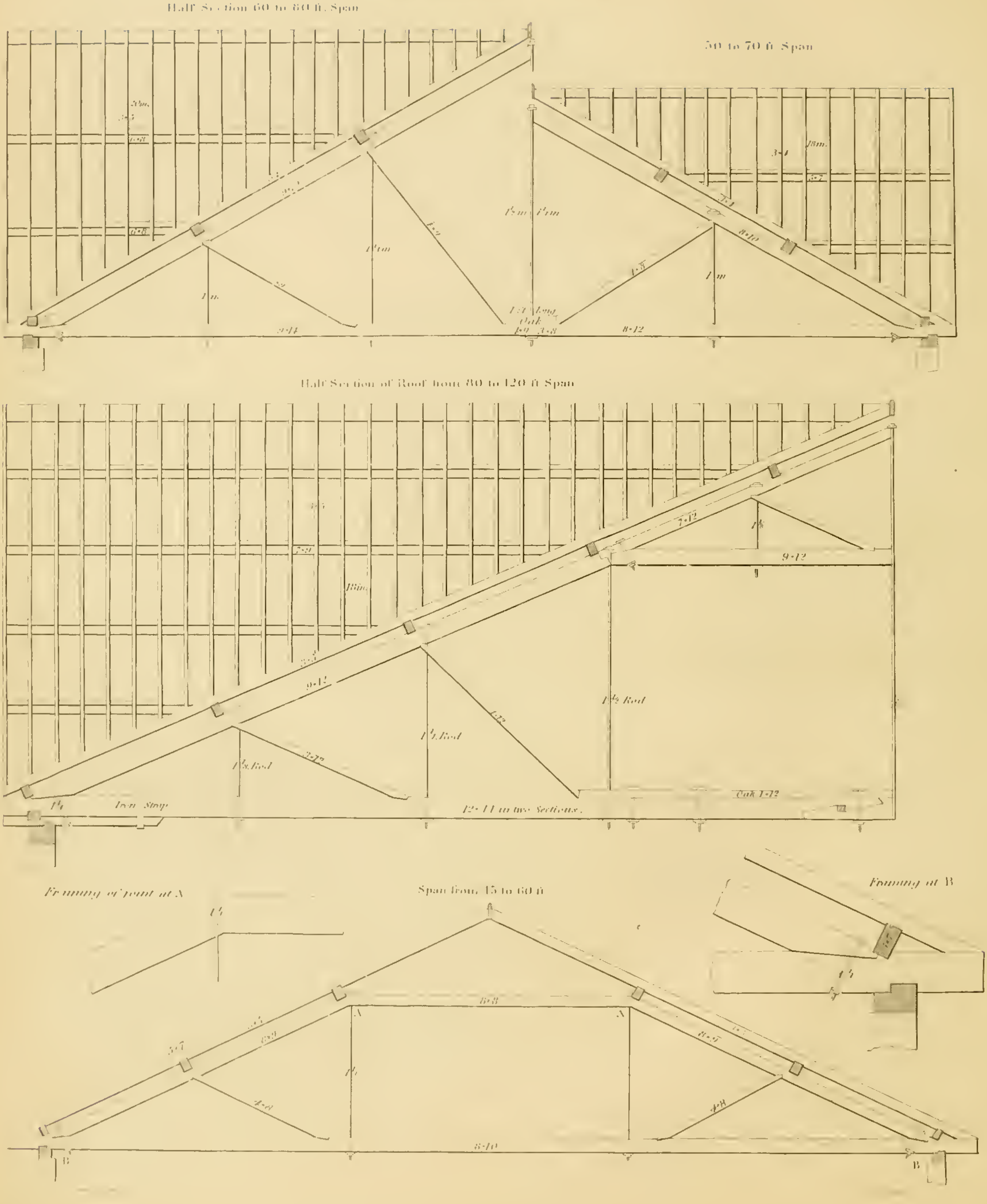
Plates 84, 85.

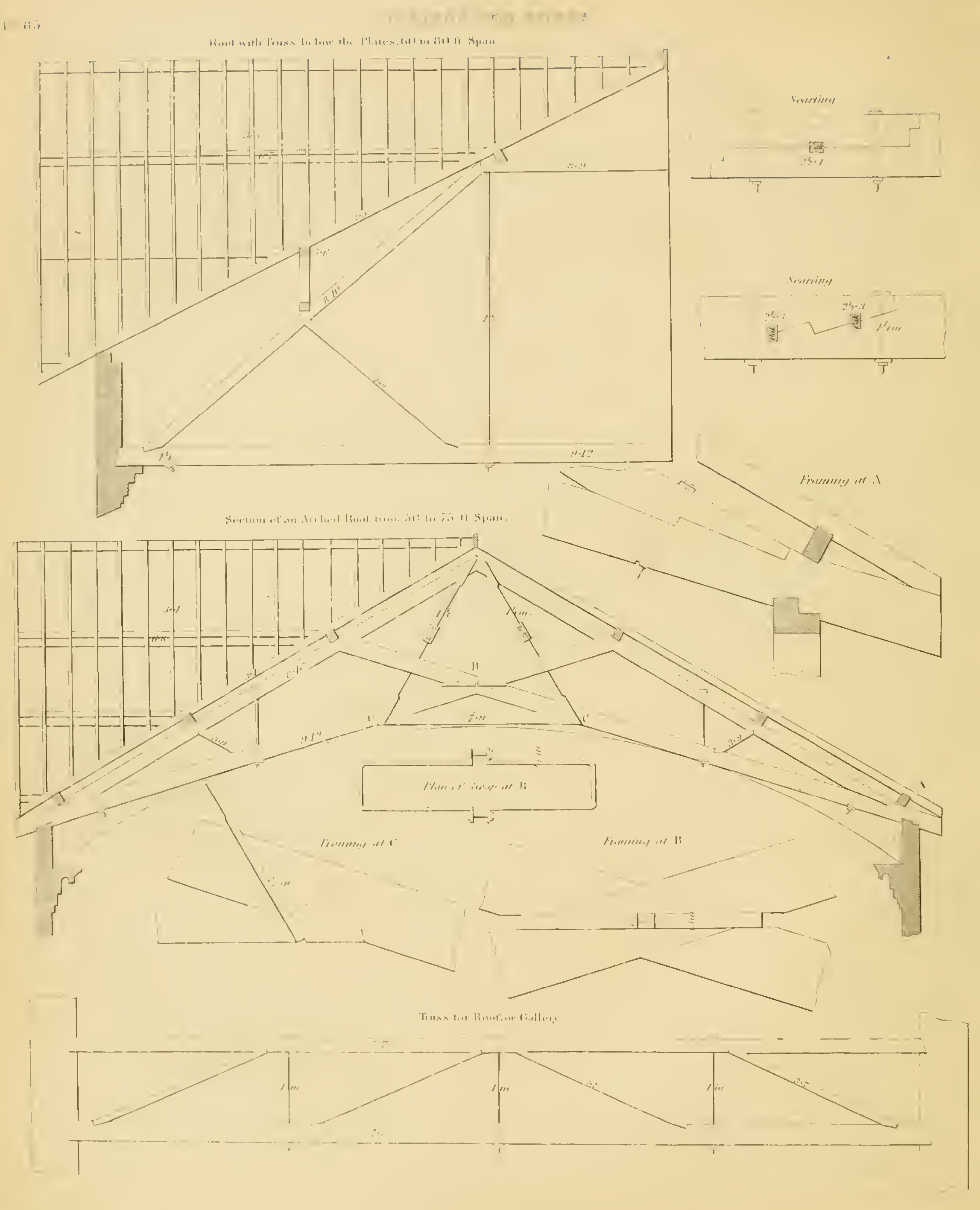
On plate Nos. 84 and 85 we have given designs for framing large roofs without wooden king or queen posts, substituting iron rods in their stead. To whom we are indebted for this method of framing we have not been able to learn with any degree of certainty. It may, however, be considered of quite modern invention; for, as the result of a careful investigation, we have found no example of longer standing than thirty years, and have not found the idea in any published work, with the exception of some of the recent writings of the late Asher Benjamin, Esq. This method was used by him as early as the year 1828, and after that time it was introduced into nearly all the large roofs he constructed; and although he may not have been the first who has used it, yet, as far as we can learn, he has done as much as any other person to introduce it into general use. It was published by him in his Builder's Guide, in 1839, and the principle involved has received the approbation of nearly all the principal architects of Boston. Mr. Charles G. Hall, architect of this city, adopted it some eighteen years since, and used it in some of the largest buildings in this vicinity. The roof over the large hall of the Fitchburg depot, in this city, is a fine example of this method of framing, and has fully demonstrated its utility. The floor of this hall is 166 feet long, and 76 feet wide, and is entirely supported by the roof. On the occasion of one of Jenny Lind's concerts which was held there, it was filled, together with the large passage, to its utmost capacity, which, according to the experiments of Tredgegold, Rennie, etc., was no less than the enormous weight of 1,873,960 pounds, or nearly 937 tons; and, so far as can be ascertained, this roof resisted the immense strain without any material settlement. Although by this system no new principle is established, yet it may be looked upon as one of the most successful achievements in the science of carpentry, and it has added as much to the science as did the arch to masonry. It has been introduced in many forms, and employed in many ways; and in every case where a due propriety has been observed in regard to the size of timber employed in the truss, it has given entire satisfaction. But the great simplicity of the theory has, in some cases, led to its abuse; and as an illustration of this, we have but to refer to a design for an arched roof as constructed by the author of the Builder's Guide, and shown on plate 64 of that work. In this example are two rods, some forty feet long, and they must necessarily be expanded so much by the heat of our summer as to relieve itself from the strain it is intended to support, so that at times the whole weight must come directly on the tie beams, which would materially loosen the whole truss. We speak of this with all deference to the knowledge and experience of the author, yet we cannot see that the experiment can philosophically recommend itself in a roof of seventy feet span. We are aware that the same objection can be brought to a certain degree against the whole theory of substituting rods for the posts; yet when we take into consideration the fact that, in nearly all roofs framed with rods in the ordinary way, the purlines are well supported by the large truss rafter and the collar beam,— that the truss without the rods would, if well executed, almost sustain itself, and that the rods are not only proportionably shorter, but differently applied,—we cannot see that any fears need be entertained in case of the latter, as may be with the former. With a degree of propriety, therefore, and an adherence to the principles of strength and support, the new method may be used in an endless variety of ways; and there is now no reasonable excuse for the uneven roofs which are so often presented to view in many of our churches and other large buildings.—Editors.

Plate 86.

Fig. A shows how to glue up the head of a niche

DESIGNS FOR ROOFS,





Scarfing
Scarfing
Framing at A
Section of an Arched Roof from 50 to 75 ft Span.
B
C
C
Framing at C
Framing at B
Truss for Roof or Gallery

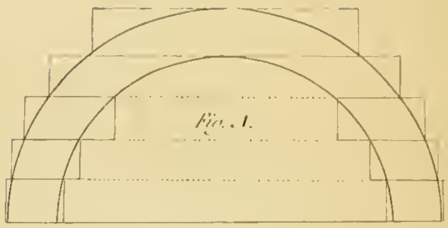


Fig. A.

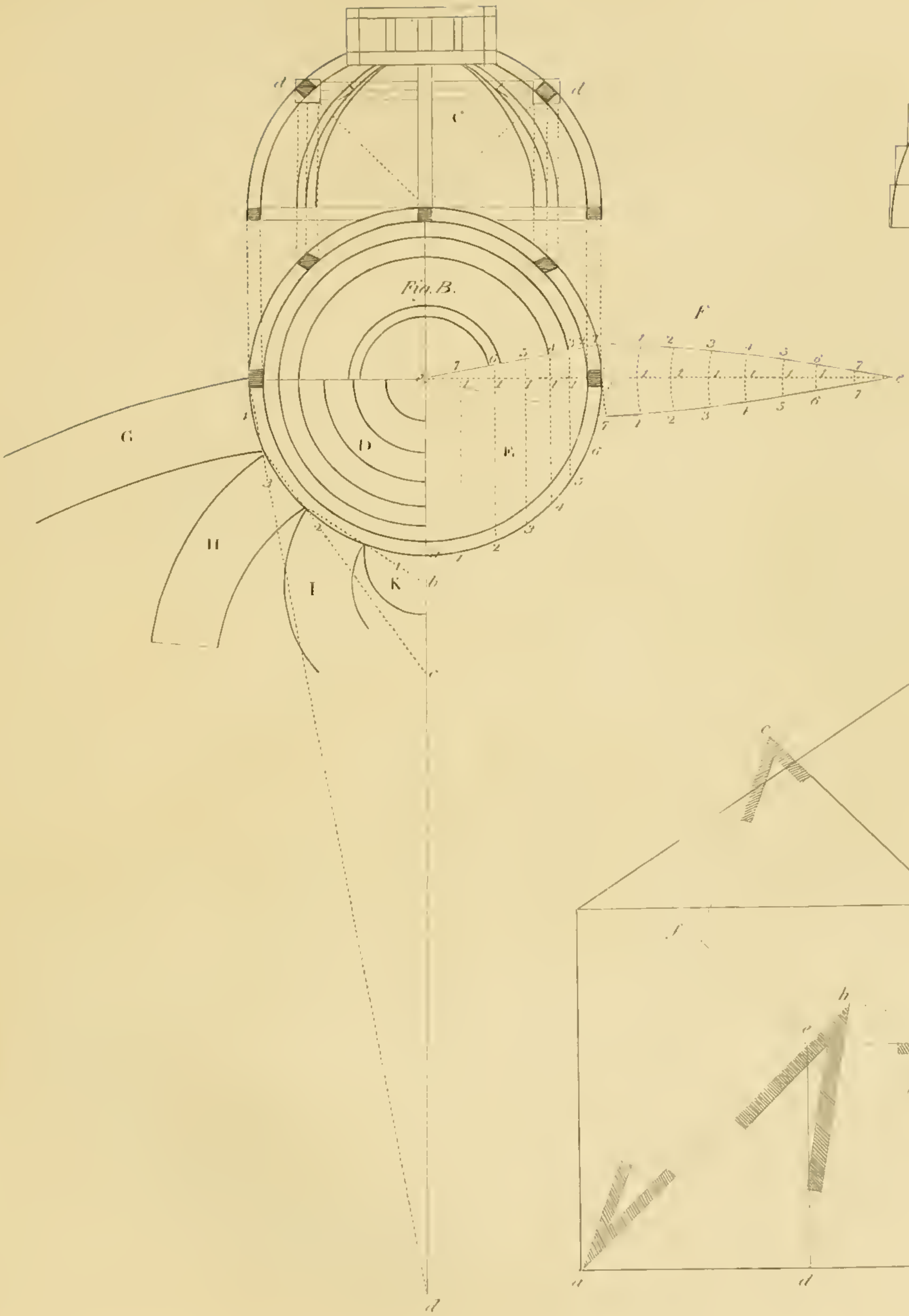


Fig. B.
C
D
E
F
G
H
I
K
d
d
b
c
e

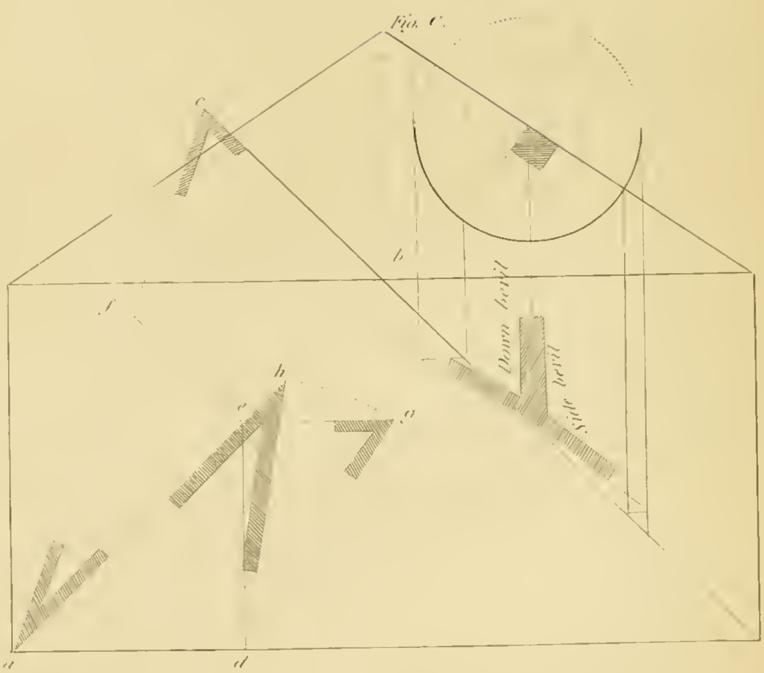


Fig. C.
Down bevil
Side bevil
a
b
c
d
f
g
h

in five or more blocks, or rings, according as the workmen shall deem expedient.

Fig. B is the plan of a circular dome; C the section, which shows at *d* and *d* how to square the purlines, so as to make them tend to the centre, or to stand square to the surface of the dome; but there is not the least occasion for the squaring of any purlines, which is attended with a deal of trouble and waste of stuff; you need only to get them out of the same curve as that of a great circle of a sphere, of which the dome is a segment, and quite square at the same time, which purlines being fixed between the ribs, the middle of them will be above the level at the joints, but will be in the true surface of the dome, and stand in a plane surface to the centre.

To find the form of a board to bend upright to the crown.

Divide E into eight parts; that is, one quarter or any other number — the more the truer; set one on the outside of 1 1 1, &c.; draw 7 *e* and 1 *e* to *e* in the centre; take the divisions 1 2 3 4, &c., round E, and lay them from 8, in F, along the line 1 1 1 1, &c.; then circle them round *e*, and take 1 1, 1 2, 1 3, &c. in E, and set them off on each side to 1 1, 1 1, 1 2, 1 2, 1 3, 1 3, &c.; those, when traced, will give the form of the board F.

To find the centres for bending the boards horizontal in D.

It is evident, the more parts any thing of this nature is divided into, the truer it will be; but I shall only divide into four, for the sake of conveniency. Draw 4 3, to meet the perpendicular at *d;* and 3 2, to meet at *c*, &c.; then *d c b a* will be the centres for the boards G, H, I, K.

Fig. C is a method of finding the length and bevel of hip and jack rafters.

The Hip Rafter. — *a b* is the base line; *c* the perpendicular height; draw a line *a c;* then *c* is the bevel at the highest point of the king post, *a* the bevel at the beam, and *a c* the length of the hip rafter.

To find the bevel and length of the jack rafters.

d e is the base line, *e f* the height equal to *e g;* then *d e g* is the right angle; describe an arc *g h*, of which *d g* is the radius, cutting *a b* at *h;* then draw the line *h d; g* is the down bevel, and *h* the top bevel, and *h d* is the length of the jack rafter.

For this method of finding the length and bevel of *jack rafters* I am indebted to the politeness of Mr. Salmon Washburn, whose skill and ingenuity first discovered this mode, which has met with the decided approbation of the few to whom it has been communicated; and it is now published for the first time.

STAIRS.

This is one of the most important subjects connected with the art of building, and should be attentively considered, not only with regard to the situation, but as to the design and execution. The convenience of the building depends on the situation, and the elegance on the design and execution of the workmanship. In contriving a grand edifice, particular attention must be paid to the situation of the space occupied by the stairs, so as to give them the most easy command of the rooms.

"Staircases," says Palladio, "will be commendable if they are clear, ample, and commodious to ascend, inviting, as it were, people to go up. They will be clear if they have a bright and equally diffuse light; they will be sufficiently ample if they do not seem scanty and narrow to the size and quality of the fabric. But they should never be less than four feet in width, that two persons may pass each other. They will be convenient with respect to the whole building if the arches under them can be used for domestic purposes; and with respect to persons, if their ascent is not too steep and difficult, to avoid which, the steps should be twice as broad as high.

With regard to the lighting of a good staircase, a skylight, or, rather, lantern, is the most appropriate, for these unite elegance with utility; that is, admit a powerful light, with elegance in the design. Indeed, where the staircase does not adjoin the exterior wall, this is the only light that can be admitted. Where the height of a story is considerable, resting-places are necessary, which go under the name of *quarter paces* and *half paces*, according as the passenger has to pass one or two right angles; that is, as he has to describe a quadrant or semicircle. In very high stories, which admit of sufficient head room, and where the space allowed for the staircase is confined, the staircase may have two revolutions in the height of one story, which will lessen the

height of the steps; but in grand staircases only one revolution can be admitted, the length and breadth of the space on the plan being always proportioned to the height of the building, so as to admit of fixed proportions.

The breadth of the steps ought never to be more than fifteen inches, nor less than nine; the height not more than eight, nor less than five. There are cases, however, which are exceptions to all rule. When the height of the story is given in feet, and the height of the step in inches, you may throw the feet into inches, and divide it by the number of inches the step is high, and the quotient will give the number of steps.

It is a general maxim, that the greater breadth of a step requires less height than one of less breadth. Thus, a step of 12 inches in breadth will require a rise of 7 inches, which may be taken as a standard to regulate those of other dimensions.

Though it is desirable to have some criterion as a guide in the arrangement of a design, yet workmen will, of course, vary them as circumstances may require. Stairs are constructed variously, according to the situation and destination of the building.

Geometrical stairs are those which are supported by having one end fixed in the wall, and every step in the ascent having an auxiliary support from that immediately below it, and the lowest step from the floor.

Bracket stairs are those which have an opening or well with strings and newels, and are supported by landings and carriages. The brackets are mitred to the ends of each riser, and are fixed to the string board, which is moulded below like an architrave.

Dog-legged stairs are those which have no opening or well hole, and have the rail and balusters of both the progressive and returning flights falling in the same vertical planes, the steps being fixed to strings, newels, and carriages, and the ends of the steps of the inferior kind terminating only upon the side of the string, without any nosing. In taking dimensions and laying down the plan and section of staircases, take a rod, and, having ascertained the number of steps, mark the height of the story by standing the rod on the lower floor; divide the rod into as many equal parts as there are to be risers; then, if you have a level surface to work upon below the stair, try each of the risers as you go on, and this will prevent any excess or defect; for any error, however small, when multiplied, becomes of considerable magnitude, and even the difference of an inch in the last riser will not only have a bad effect to the eye, but will be apt to confuse persons not thinking of any such irregularity. In order to try the steps properly by the story rod, if you have not a level surface to work from, the better way will be to lay two rods on boards, and level their top surface to that of the floor. Place one of these rods a little within the string, and the other near or close to the wall, so as to be at right angles to the starting line of the first riser, or, which is the same thing, parallel to the plan of the string; set off the breadth of the steps upon these rods, and number the risers; you may set not only the breadth of the fliers, but that of the winders also. In order to try the story rod exactly to its vertical situation, mark the same distances of the risers upon the top edges as the distances of the plan of the string board and the rods are from each other.

In bracket stairs, as the internal angle of the steps is open to the end, and not closed by the string as in common dog-legged stairs, and the neatness of workmanship is as much regarded as in geometrical stairs, the balusters must be neatly dovetailed into the ends of the steps, two in every step. The face of each front baluster must be in a straight surface with the face of the riser, and, as all the balusters must be equally divided, the face of the middle baluster must stand in the middle of the face of the riser of the preceding step and succeeding one. The risers and heads are all previously blocked and glued together, and, when put up, the under side of the step nailed or screwed into the under edge of the riser, and then rough brackets to the rough strings, as in dog-legged stairs, the pitching pieces and rough strings being similar. In gluing up the steps, the best method is to make a templet, so as to fit the external angle of the steps with the nosing.

The steps of geometrical stairs ought to be constructed so as to have a very light and clean appearance when put up; for this purpose, and to aid the principle of strength, the risers and treads, when planed up, ought not to be less than one eighth of an inch, supposing the going of the stair or length of the step to be four feet; and for every six inches in length, another one eighth may be added. The risers ought to be dovetailed into the cover, and, when the steps are put up, the treads are screwed up

from below to the under edge of the risers. The holes for sinking the heads of the screws ought to be bored with a centre bit, then fitted closely in with wood, well matched, so as entirely to conceal the screws, and appear as one uniform surface. Brackets are mitred to the riser, and the nosings are continued round. In this mode, however, there is an apparent defect; for the brackets, instead of giving support, are themselves unsupported and dependent on the steps, being of no other use, in point of strength, than merely tying the risers and treads of the internal angles of the step together; and, from the internal angles being hollow, or a reëntrant angle, except at the ends, which terminate by the wall at one extremity, and by the brackets at the other, there is a want of regular finish. The cavetto or hollow is carried round the front of the riser, and is returned at the end and mitred round the bracket; and if an open string, — that is, the under side of the stairs open to view, — the hollow is continued along the angle of the step and riser.

The best plan, however, of constructing geometrical stairs, is to put up the strings, and to mitre the brackets to the risers, as usual, and enclose the soffit with lath and plaster, which will form an inclined plane under each flight, and a winding surface under the winders. In superior staircases, for the best buildings, the soffit may be divided into panels. If the risers are made from two-inch planks, it will greatly add to the solidity.

In constructing a flight of geometrical stairs where the soffit is enclosed as above, the bearers should all be framed together, so that, when put up, they will form a perfect staircase. Each piece of framework which forms a riser should, in the partition, be well wedged at the ends. This plan is always advisable when strength and firmness are requisite, as the steps and risers are entirely dependent on the framed carriages, which, if carefully put together, will never yield to the greatest weight.

In preparing the string for the wreath part, a cylinder should be made of the size of the well-room of the staircase, which can be done at a trifling expense; then set the last tread and riser of the fliers on one side, and the first tread and riser of the returning flight on the opposite side, at their respective heights; then, on the centre of the curved surface of this cylinder, mark the middle between the two, and with a thin slip of wood bent round with the ruling edge, cutting the two nosings of these fliers, and, passing through the intermediate height marked on the cylinder, draw a line, which will give the wreath line formed by the nosings of the winders; then draw the whole of the winders on this line by dividing it into as many parts as you want risers, and each point of division is the nosing of such winder. Having thus far proceeded, and carefully examined your heights and widths, so that no error may have occurred, prepare a veneer of the width intended for your string, and the length given by the cylinder, and, after laying it in its place on the cylinder, proceed to glue a number of blocks about an inch wide on the back of the veneer, with their fibres parallel to the axis of the cylinder. When dry, this will form the string for the wreath part of the staircase, to be framed into the straight strings. It is here necessary to observe, that about five or six inches of the straight string should be in the same piece as the circular, so that the joints fall about the middle of the first and last fliers. This precaution always avoids a cripple, to which the work would otherwise be subject.

The branch of stair building that falls under our next and last consideration is that of hand railing, which calls into action all the ingenuity and skill of the workman. This art consists in constructing hand rails by moulds, according to the geometrical principles, that, if a cylinder be cut in any direction except parallel to the axis or base, the section will be an ellipsis; if cut parallel to the axis, a rectangle; and if parallel to the base, a circle.

Now, suppose a hollow cylinder be made to the size of the well-room of the staircase, the interior concave and the exterior convex, and the cylinder be cut by any inclined or oblique plane, the section formed will be bounded by two concentric similar ellipses; consequently, the section will be at its greatest breadth at each extremity of the larger axis, and its least breadth at each extremity of the smaller axis. Therefore, in any quarter of the ellipsis there will be a continued increase of breadth from the extremity of the lesser axis to that of the greater. Now, it is evident that a cylinder can be cut by a plane through any three points; therefore, supposing we have the height of the rail at any three points in the cylinder, and that we cut the cylinder through these points, the section will be a figure equal and similar to the face mould of the rail; and if the

cylinder be cut by another plane parallel to the section, at such a distance from it as to contain the thickness of the rail, this portion of the cylinder will represent a part of the rail with its vertical surfaces already worked: and again, if the back and lower surface of this cylindric portion be squared to vertical lines, either on the convex or concave side, through two certain parallel lines drawn by a thin piece of wood, which is bent on that side, the portion of the cylinder thus formed will represent the part of the rail intended to be made.

Though the foregoing only relates to cylindrical well-rooms, it is equally applicable to rails erected on any seat whatever.

The *face mould* applies to the two faces of the plank, and is regulated by a line drawn on its edge, which line is vertical when the plank is elevated to its intended position. This is also called the *raking mould.*

The *falling mould* is a parallel piece of thin wood applied and bent to the side of the rail piece, for the purpose of drawing the back and lower surface, which should be so formed that every level straight line directed to the axis of the well-room, from every point of the side of the rail formed by the edges of the falling mould, coincide with the surface.

In order to cut the portion of rail required out of the least possible thickness of stuff, the plank is so turned up on one of its angles that the upper surface is nowhere at right angles to a vertical plane passing through the chord of the plane; the plank in this position is said to be *sprung.*

The *pitch board* is a right-angled triangular board made to the rise and tread of the step, one side forming the right angle of the width of the tread, and the other of the height of the riser. When there are both winders and fliers, two pitch boards must be made to their respective treads, but, of course, of the same height, as all the steps rise the same.

The bevel by which the edge of the plank is reduced from the right angle when the plank is sprung, is termed the *spring of the plank*, and the edge thus bevelled is called the *sprung edge.*

The bevel by which the face mould is regulated to each side of the plank is called the *pitch.*

The formation of the upper and lower surface of a rail is called the *falling of the rail;* the upper surface of the rail is termed the *back.*

In the construction of hand rails, it is necessary to spring the plank, and then to cut away the superfluous wood, as directed by the drawings, formed by the face mould, which may be done by an experienced workman so exactly with a saw as to require no further reduction; and when set in its place, the surface on both sides will be vertical in all parts, and in a surface perpendicular to the plan. In order to form the back and lower surface, the falling mould is applied to one side, generally the convex, in such a manner that the upper edge of the falling mould at one end coincides with the face of the plank, and the same in the middle, and leaves so much wood to be taken away at the other end as will not reduce the plank on the concave side; the piece of wood to be thus formed into the wreath or twist being agreeable to their given heights.

Plate 87.

To find the projection of a helinet, on a plane parallel to the axis of the cylindrome and perpendicular to the cutting plane of the solid.

Figs. 3 and 4. Let A B C D E F G H I K L M A, (Fig. 3,) be the plan of a helinet, the quadrantal part being B C D E F G H I K L B, and the straight part being A B L M A.

Let Fig. 4 be the falling mould, corresponding to the concave side of the semi-cycloid, found in the usual manner, viz., draw any straight line X V W *u;* make U V equal to the breadth of one of the fliers, and V X equal to the stretch of B F; draw X *n* perpendicular to U X, equal to the height of as many winders as are contained in the circular part, together with the height of the flier; draw V *t* perpendicular to U X, equal in height to a step, and join *t n;* then complete the falling mould, of which the under edge is *n o p q r a* U, and the upper edge *z s t u* V W X; make V W equal to B A, in Fig. 3; draw W *a* perpendicular to X U, cutting the under side of the falling mould at *a*, and *a f* parallel to U X; then *a f* is the stretch of A B C D E F, Fig. 3. In Fig. 3, divide the quadrant B F into any equal parts, B C, C D, D E, E F, which stretch upon *a f*, Fig. 4, according to the corresponding letters. In Fig. 3, bisect C D at I; draw I P radiating to the centre N, cutting the convex side of the plan at P; draw F P R and F O and P Q parallel to each other, making an angle with F R. In Fig. 4, bisect *c d* in *y*, and draw *y y* perpendicular to *a f*, uniting the under edge of the falling mould at *y;* divide *f n* and *y y* each into

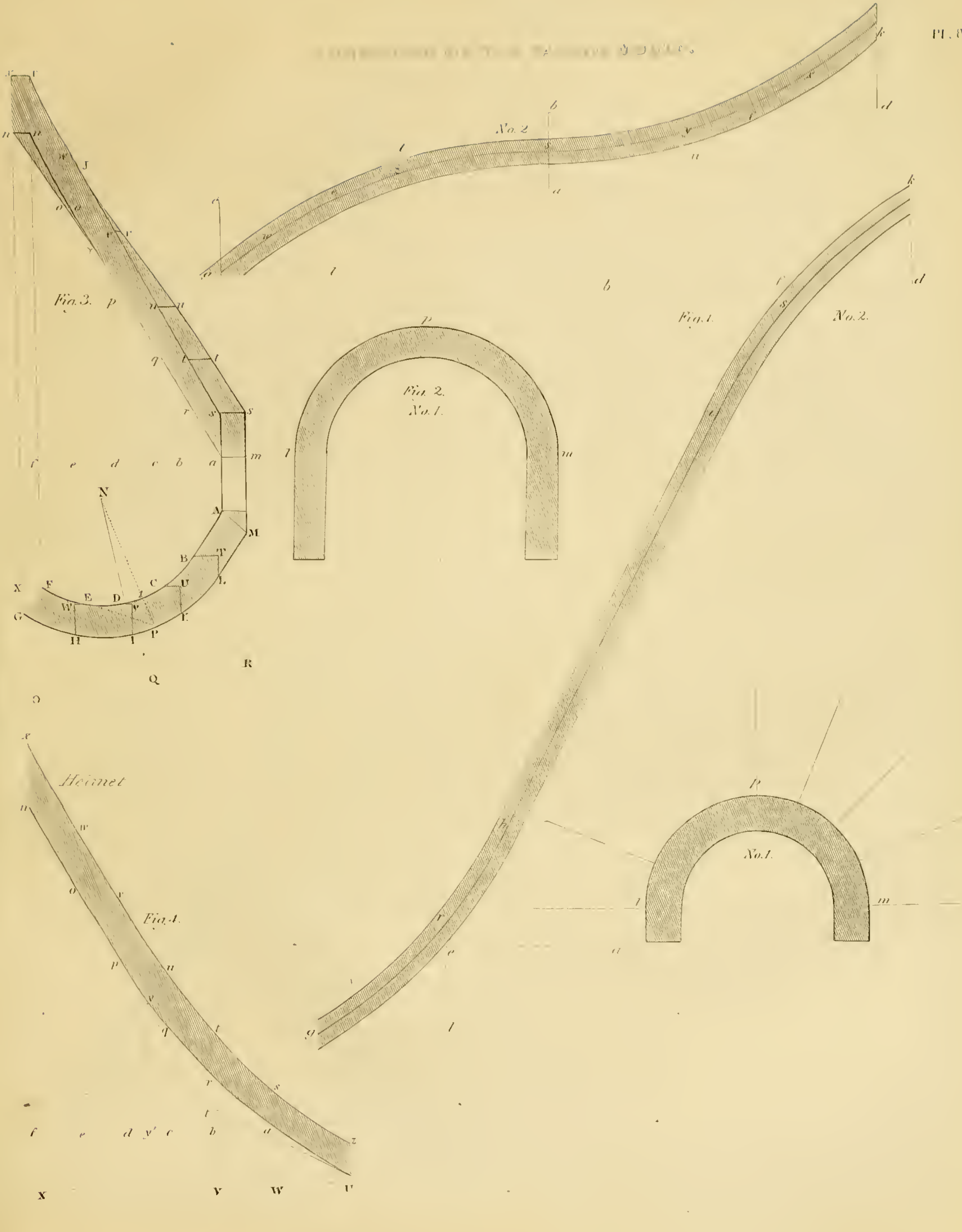

No. 2
Fig. 3.
Fig. 2.
No. 1.
Fig. 1.
No. 2.
No. 1.
Fig. 4.

Fig. 1
Fig. 2
Fig. 3
Fig. 4
Fig. 5
Fig. 6
Fig. 7

the same number of equal parts as here into three. In Fig. 3, make F O equal to one third of $f\ n$, and P Q equal to one third of $y\ y$; join O Q, which produce to meet F P in R. Draw R M, which produce to s. In R s take any point m, and draw $m\ f$ perpendicular to R s; then, parallel to R s, draw A a s, B $b\ r\ t$, C $c\ q\ u$, D $d\ p\ v$, E $e\ o\ w$, F $f\ n\ x$.

From Fig. 4 transfer the heights $b\ r$, $c\ q$, $d\ p$, $e\ o$, and $f\ n$, to the corresponding lines $b\ r$, $c\ q$, $d\ p$, $e\ o$, $f\ n$, Fig. 3; also, from Fig. 4 transfer the lines $a\ s$, $r\ t$, $q\ u$, $p\ v$, $o\ w$, and $n\ x$, to $a\ s$, $r\ t$, $q\ u$, $p\ v$, $o\ w$, and $n\ x$, Fig. 3; then through the points $n\ o\ p\ q\ r\ a$ draw a curve, which will be the line representing the under edge of the inside falling mould; also, draw the curve $x\ w\ v\ u\ t\ s$, which is the line representing the upper edge of the same falling mould. The upper and lower edges of the outside falling mould will thus be found — N being the centre of the quadrants B C D E F and G H I K L; draw N E H, N D I, N C K, N B L, cutting the convex side at H, I, K; and draw H W, I V, K U, L T, parallel to R s; and E W, D V, C U, B T, parallel to $f\ m$. Also, draw $s\ s$, $t\ t$, $u\ u$, $v\ v$, parallel to $f\ m$; and make $t\ t$, $u\ u$, $v\ v$, respectively equal to T B, U C, V D; and complete the parallelogram $t\ t$, $s\ s$, and draw the curve $t\ u\ v$ J, which will meet the curve $s\ t\ u\ v\ w\ x$ at J, the point where a perpendicular drawn from the centre N of the quadrant meets it. In the same manner, find the curve $n\ o\ r$; and we shall have the whole projection of the helinet, which will give the thickness of the stuff required to make the rail; by drawing a straight line in contact with two points on the under side without cutting the solid, and another parallel to it from the point X, then the distance between these parallel lines is the thickness of the stuff.

ON THE FORMATION OF THE FALLING MOULD.

To find the falling mould for a semicircular stair, with winders round the semicircular part; or the falling mould for a semicircular staircase level round the semicircle, joined below and above the fliers.

No. 1, Fig. 1, is in the plan of the rail round the circular part, and of a small portion of the straight part with the seats or plans of the risers round the semicircular part.

Make $a\ b$, No. 2, equal to the height of the winders; draw $a\ e$ and $b\ d$ at right angles with $a\ b$; make $a\ e$ and $b\ f$ each equal to the development of $l\ p$ or $p\ m$, (No. 1;) draw $e\ l$ and $d\ k$ parallel to $a\ b$; make $e\ l$ and $d\ k$ each equal to the height of a step; and join $e\ g$ and $f\ k$. This description so far applies both to Figs. 1 and 2.

In Fig. 1, No. 2, join $e\ f$; make $e\ h$ equal to $e\ g$, and $f\ i$ equal to $f\ k$, and draw the touching curves $g\ r\ h$ and $i\ s\ k$; and $g\ r\ h\ i\ s\ k$ will be the line of the rail.

In Fig. 2, No. 2, produce $g\ e$ to t, and $k\ f$ to u; bisect $a\ b$ at s, and through s draw $t\ u$ parallel to $a\ c$ or $b\ d$; from $g\ t$ cut off $t\ w$, and from $u\ k$ cut off $u\ x$, each equal to $g\ e$ or $f\ k$; and describe the touching curves $g\ z\ s$ and $s\ y\ x$, and $g\ w\ z\ s\ y\ x\ k$ will be the line of rail.

The breadth of the falling mould in common cases is about two inches; therefore, draw the curve lines each at an inch distance from the line of the rail, and the falling mould will be completed.

Plate 88.

ON THE RESTING POINTS.

PROBLEM.

To find the position of the plane of the plank, and the resting points, so that the thickness of stuff required to make the helinet may be the least possible.

Fig. 1. Let $a\ b\ c\ d\ e\ f\ g\ h$ be the plan of the rail, of which the part $b\ c\ d\ e\ f\ g$ is the quadrant of a circle, and the part $a\ b\ g\ h$ of a rectangular figure; the straight lines $a\ b$ and $h\ g$ being tangents to the outer and inner arcs at b and g, and the circular quadrants $b\ c\ d$ and $g\ f\ e$ terminated by the radii $b\ l$ and $g\ l$; then suppose two equal straight lines, one erected upon c and the other upon f, perpendicular to the plane of the plan of the rail, and let $c\ l$ be any intermediate radius, cutting the interior quadrant at f; produce $a\ h$ and $c\ l$ to meet each other in k.

Now, if a straight line be supposed to extend from k to the top of the line which stands upon f, the straight line thus extended, if produced, would be higher than the top of the line which stands upon c; therefore, if a plane pass through $a\ k$ and through the top of the line insisting upon f, the plane will pass above the top of the line standing upon c, and this will be the case with every section, except the section $b\ g$, which is parallel to $a\ k$; therefore, if the plane

of the plank rest upon the lower section $a\ h$, and upon any other two points in the circular part, these points must be in the concave side; therefore, in this case, the resting points are upon h, f, e, in the concave side of the rail.

Again: in Fig. 2, let $l\ c$ and $a\ b$ be produced to meet each other in k; then if a straight line be extended from k to the top of the line which stands upon c, the straight line thus extended, if produced, would be higher than the top of the line which stands upon f; therefore, the plane which passes through $a\ b$, and through the top of the line which insists upon c, will be above the point which terminates the top of the line insisting upon f; whence the resting points, a, c, d, are all upon the convex side of the rail.

Lastly: in Fig. 3, if a plane rests upon the top of the two lines insisting upon c and f, and pass through the point a, — and if a line be supposed to stand upon e, perpendicular to the plane of the base, of such a length as to meet the plane which passes through a, and through the upper ends of the lines insisting upon c and f, — it is evident that if another line be supposed to be erected upon d, also perpendicular to the plane of the base and equal in height to the line insisting upon e, the plane which passes through the point a, and through the tops of the lines insisting upon c, f, e, must be above the top of the line insisting upon d; and that the intersection $p\ q$ of the plane passing through a, and the points in the line insisting upon c and f, must be parallel to $c\ f$.

It is now evident that if $a\ b$ be produced to r, and $h\ a$ to s, and as the intersection always passes through a, the line $a\ p$ of the intersection of the plane must always fall within the right angle $r\ a\ s$.

It is likewise evident, if the resting section of the rail fall between $c\ f$ and $a\ h$, as at $b\ g$, the middle resting point will be over b in the convex side of the rail; and if the resting section fall between $c\ f$ and $d\ e$, the resting point of the middle section must be on the concave side.

SCHOLIUM I.

In stairs constructed upon the letter D plan, with winders in the semicircular part, joined to a series of fliers below and above, where the winders have a higher pitch than the fliers, the first two resting points, beginning at the lowest point, will be on the convex side of the rail, while that at the highest point is on the concave side.

Fig. 4. When the lower line of heights is nothing, and the highest double to the middle one, the line of intersection will be found by drawing a line through the seat of the highest and middle resting point, and producing the line on the other side of the seat of the middle resting point, until the part produced be equal to the part between the two seats, and drawing a line through the lowest point a, and through the extremity of the point thus found; then the line thus drawn will be the intersection.

Thus, in the present case, $a\ c$ and e are the resting points; join $e\ c$, and produce $e\ c$ to k; make $c\ k$ equal to $c\ e$, and join $a\ k$; then $a\ k$ is the intersection; and this agrees with what has been observed; for if $a\ k$ and $l\ c$ be produced, they will meet in m; therefore, f is not the seat of the resting point: if f were the seat of the resting point, making $f\ i$ equal to $f\ e$, and joining $a\ i$, then $a\ i$ would be the intersecting line; but it is not, for the point c is nearer to $a\ m$ than f.

Corollary. — From what has been observed, (see Fig. 5,) that the intersecting line $u\ v$ never falls within the right angle at a, or upon the plan $a\,c\,d\,e\,h$, therefore, the point c is always nearer to $u\ v$ than the point d; therefore, the point c is the seat of a resting point.

SCHOLIUM II.

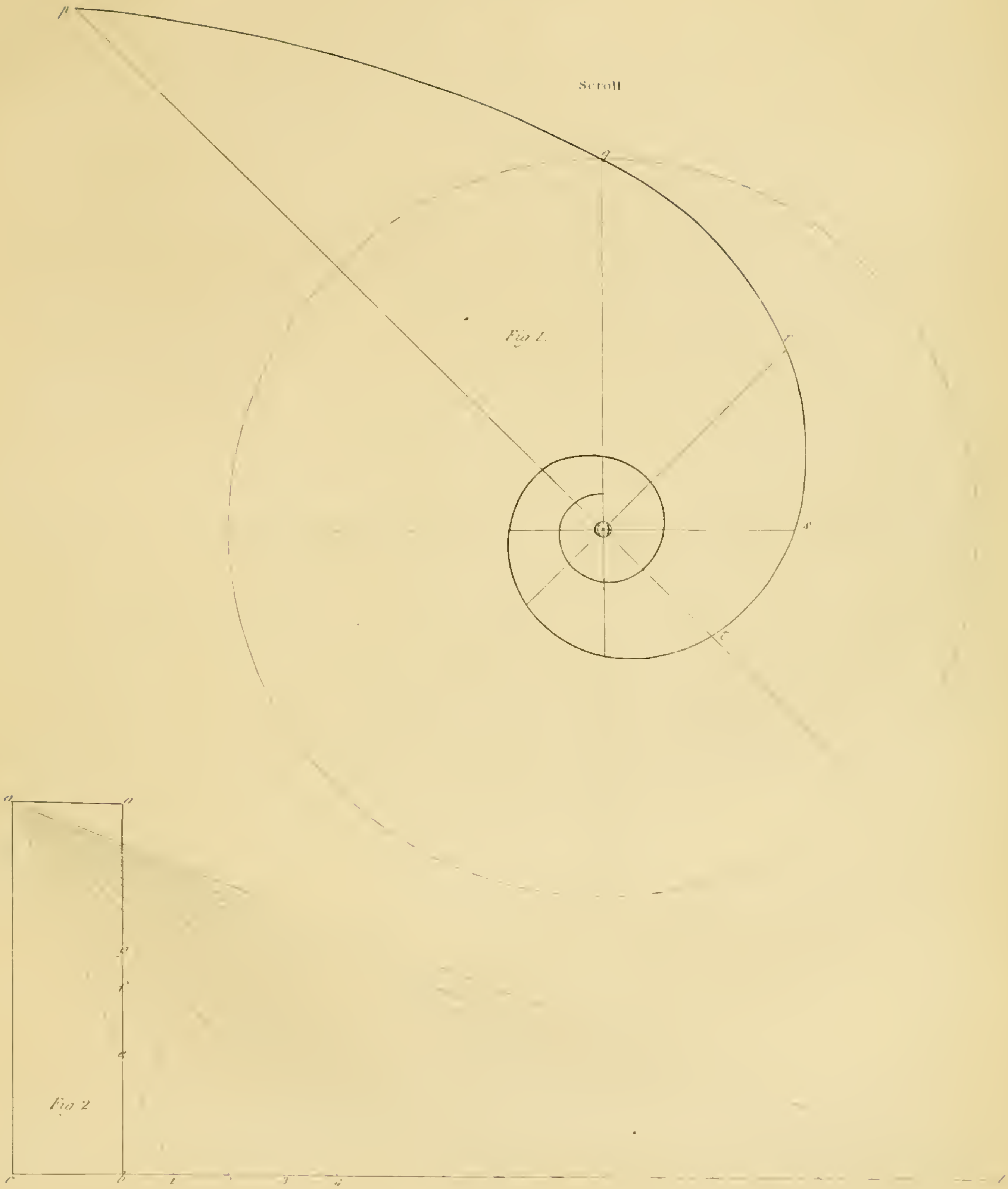
Fig. 5. From the same given heights, and from the same three resting sections of the rail, there cannot be more than four intersecting lines by making choice of one resting point from each section.

For, suppose we make choice of the points d and c as the seats of the resting points, and join the line $d\ c$, and produce $d\ c$, suppose to some imaginary point X, and find the point X from the heights upon d and c, in such a manner that the line thus drawn may not cross the plan, even if produced. The same thing may be done through the points d and f, also through the points e and c, and through the points e and f; then, whichever of the points, d or e, is nearest to the intersecting line $u\ v$, that point is the seat of the resting point.

With regard to the ratio between the whole line drawn through the seats of the resting points and the part of it between the said seats, it is the same as the ratio between the highest line and the line insisting on the seat of the middle section.

Suppose (in Fig. 5) the seats of the resting points are c and e; join $e\ c$, and produce it to i; draw $e\ l$ and $c\ k$ perpendicular to $e\ i$; make $c\ l$ equal to the

Scroll



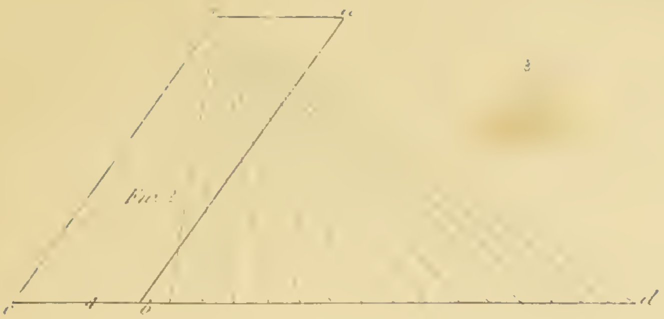


Fig. 2

Scroll

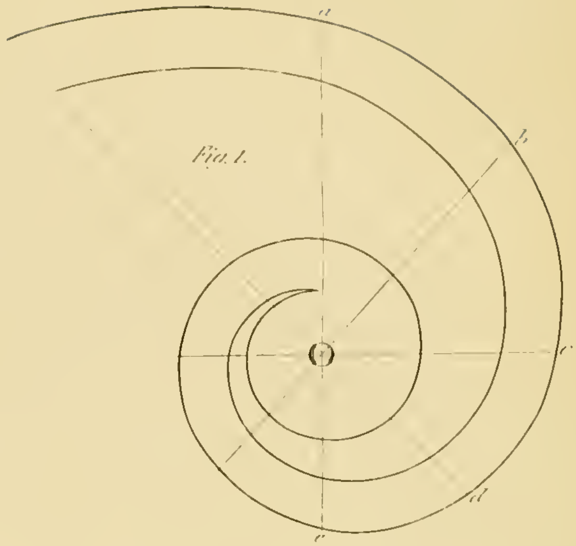


Fig. 1.

Scroll

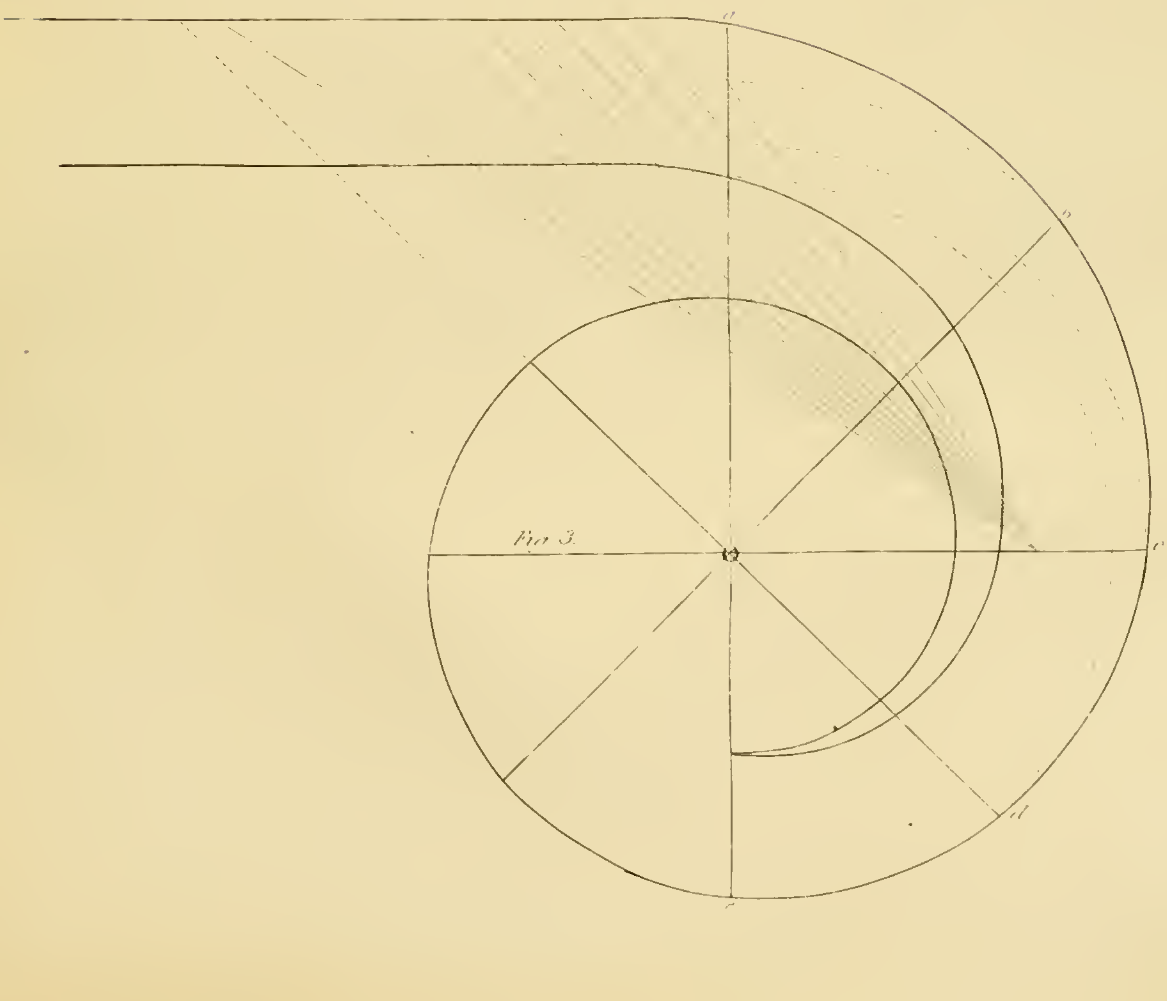


Fig. 3.

height insisting upon *e*, and *c k* equal to the height insisting upon *c;* join *l k*, and produce it to *i*. Then, because of the similar triangles *e i l* and *c i k*, *i e : i c : : e l : c k;* that is, *i c* is the same part of *i e* that *c k* is of *e l;* therefore, if *c l* be double of *c k*, *c i* will be double of *c i*, or *i c* will be equal to *c e*.

If the workman should not understand the demonstration now given, he may proceed mechanically thus, the seats of the resting points being *a*, *c*, *e*. Join *c c*, and produce *e c* to *i;* draw *e l* and *c k* perpendicular to *i e;* make *e l* equal to the height upon *e*, *c k* equal the height upon *c;* join *l k* and produce it to *i*, and join *i a;* then *i a* is the intersecting line. Produce *i a* both ways to *u* and *v*, *c f* to *o* and *v*, and *d e* to *o* and *u;* draw *d r*, *c m*, and *o q* perpendicular to *d u;* draw *o p*, *f w*, and *c n* perpendicular to *o v;* make *c n* equal to *c k*, and join *v n;* produce *v n* to *p;* mak *o q* equal to *o p*, and *e m* equal to *c l;* join *m q;* then, if *m q* be produced, it will meet *u v* in *u*. This may easily be conceived by raising the triangles *i e l*, *v o p*, and *u e m*, upon their bases, *i e*, *v c*, and *d u;* then *c k* will coincide with *c n*, *e l* with *e m*, and *o p* with *o q;* and the lines *i l*, *v p*, and *r u* will all be in the inclined plane of which its intersection is *u v*.

CONSTRUCTION OF THE FACE MOULD.

Fig. 7. Let *a d e f g h i* be the plan of the rail, *e f g h* a portion of the straight part, *i* being the upper, and *f* the lower, resting points. But as the place of the middle resting point *d* will affect the thickness of the stuff, it ought not to be arbitrarily assumed; though it would be difficult to show upon any principle where it should be exactly. It is, however, ascertained by trial that its position may vary to a considerable distance without affecting the thickness of the stuff in any great degree; and as experiment shows that it is nearly in the middle of the development of *a d e f*, it is here taken in the middle, so that the stretch-out of *a d* may be equal to the stretch-out of *d f*.

Figs. 6 and 7. In the figure of the falling mould, produce the base *a e* of the winders to *f*, then *a e* (Fig. 6) being equal to the development of *a c*, (Fig. 7,) make *a d* (6) equal to the development of *a d*, (7,) and make *e f* (6) equal to *c f*, (7;) draw *f l* parallel to *a b*, (6,) cutting the upper side of the falling mould at *l*, (6;) parallel to *f a* draw *l i*, cutting *a b* at *i*, (6;) in *i l* make *i d* (6) equal to *i d*, (7;) draw *d m* (6) parallel to *a b*, cutting the upper side of the falling mould at *m;* draw *m n* parallel to *f a*, cutting *a b* at *n;* draw *d r* parallel to *a b*, cutting *m n* at *r*, (6.)

Join *o r*, and produce it to meet *i l* at *q;* make *i q* (7) equal to *i q*, (6;) join *f q*, (7,) and produce *f q* to *k i*. Through *g* draw *k l* perpendicular to *k q*. Through *i* draw *i z* parallel to *k q*, cutting *k l* at *z*. Make *z z* equal to *io*, (6;) and join *k z*, (7,) and produce *k z* to *l:* draw *a l* parallel to *z z*.

TO FIND THE FACE MOULD.

Fig. 7. Draw *l a* and *z b* perpendicular to *k l;* make *l a* equal to *l a*, *z i* equal to *z i*, and join *i a;* then *i a* will form the part of the face mould represented by *i a* on the plan. Draw *k f* perpendicular to *k l*, and make *k f* equal to *k f*. Draw *g g* parallel to *z z*, cutting *k l* at *g*, and join *g f*. Again: draw *h u* parallel to *z z*, cutting *k l* at *u* and *k l* at *u*. Draw *u h* perpendicular to *k l*, and make *u h* equal to *u h;* draw *h e* parallel to *g f*, and *f e* parallel to *g h;* then *e f g h* will form the part of the face mould corresponding to the straight part *e f g h*, in the plan. The intermediate points of the face mould, which form curves of the outside and inside of the rail, are thus found. Through any point *c*, in the convex side of the plan, draw *c y* parallel to *z z*, cutting *k l* at *y i*, and *k l* at *y*, and the concave side of the plan at *t*. Draw *y c* perpendicular to *k l*, and in *y c* make *y t* equal to *y t*, and *y c* equal to *y c;* then *t* is a point in the concave side, and *c* a point in the convex side, of the face mould. A sufficient number of points being thus found, the curved parts of the face mould may be drawn by hand, or by a slip of wood bent to the curve.

It will be perceived that I have been obliged, in some instances, to use the same letter of reference twice; but they are so placed, that the one referred to can be ascertained without any difficulty.

Plates 89 & 90.

RECIPROCAL SPIRAL AND SCROLL.

To draw the reciprocal spiral for a scroll.

Suppose the ordinate *o q* (Fig. 1) to be given. Make *a b* (Fig. 2) equal to *o q*, and through *b* draw *c d*, making an angle with *a b;* then take *b c* in a greater or less ratio to *b* 1, as a less or greater part of the scroll is wanted, or as the scroll is required to

have a flatter or quicker curve at the remote extremity; for instance, $b\ c$ in this example is double to b 1.

Suppose the point c to be now fixed; draw $c\ e$ parallel to $a\ b$, and $a\ e$ parallel to $c\ d$; make 1, 2; 2, 3; 3, 4; &c., each equal to b 1, and draw the lines 1 e, 2 c, 3 c, 4 c, &c., cutting $a\ b$ respectively at $e\ f\ g$, &c.

In Fig. 1, divide the space round the centre o into eight equal angles, which will be easily done by drawing a circle through q, and dividing the circumference into eight equal parts, beginning at q; draw the portions $o\ p$, $o\ q$, $o\ r$, $o\ s$, &c. Make $o\ p$ (Fig. 1) equal to twice $a\ b$, (Fig. 2;) $o\ q$ (Fig. 1) is equal to $a\ b$, (Fig. 2;) also, make $o\ r$, $o\ s$, $o\ t$, &c., (Fig. 1,) respectively equal to $a\ c$, $a\ f$, $a\ g$, &c., (Fig. 2.) Through all the points $p\ q\ r\ s\ t$, &c., draw the curve $p\ q\ r\ s\ t$, &c., which will be the spiral required.

For want of room, $a\ b$ (Fig. 2) is only made equal to half the length it ought to have been; for $a\ b$ will be divided into parts of the same length, whether $a\ b$ is double and $b\ c$ equal to b 1, or $a\ b$ as it is, and $b\ c$ double of b 1.

SCHOLIUM.

This spiral is well adapted to the purpose of hand railing, for it may be made close or to extend at pleasure, as may be seen by the subsequent examples.

This spiral may be extended so as to form the rail itself by a gentle curve, which will approach nearer to a straight line the more it is extended. The forms of stairs attached to pulpits are often very fanciful; their plan requires to be formed in the most graceful manner; the reciprocal spiral may be applied to this purpose with advantage, as the effect produced will be both beautiful and elegant. It may also be applied to form the plan of the riser of the curtail step into a gentle curve, which will be in perfect unison with the scroll itself. The plans of the other steps may be formed to the same curve; but the curvature may be made less in each, as the other risers recede from that of the curtail step, till at last the risers become straight. The property of this scroll may be shown arithmetically, thus: let any given radius be called unity, or one, and let this radius, so called, be the greatest radius; let n be any constant number, which must be in the same scroll, but variable in different scrolls, and let x be a variable number in the same scroll, then will $\frac{n}{x+n}$ represent any ordinate; thus the first, second, third, &c., ordinates, by making x respectively 0, 1, 2, 3, &c., will be respectively $\frac{n}{n}$, $\frac{n}{n+1}$, $\frac{n}{n+2}$, &c. By giving n a value, the form of the scroll will be determined. Thus, make $n=2$, and we shall have the series of ordinates, $\frac{2}{2}$, $\frac{2}{3}$, $\frac{2}{4}$, $\frac{2}{5}$, $\frac{2}{6}$, &c.

This will give the scroll Fig. 1, plate 91.

Make $n=4$; then $\frac{n}{n}$, $\frac{n}{n+1}$, $\frac{n}{n+2}$, $\frac{n}{n+3}$, &c. will become $\frac{4}{4}$, $\frac{4}{5}$, $\frac{4}{6}$, $\frac{4}{7}$, &c., respectively. These are the respective ratios of the ordinates $o\ a$, $o\ b$, $o\ c$, $o\ d$, $o\ c$, &c., Fig. 1, plate 88.

Lastly: make $n=8$; then $\frac{n}{n}$, $\frac{n}{n+1}$, $\frac{n}{n+2}$, $\frac{n}{n+3}$, &c., will become $\frac{8}{8}$, $\frac{8}{9}$, $\frac{8}{10}$, $\frac{8}{11}$, &c., respectively. These are the respective ratios of the ordinates $o\ a$, $o\ b$, $o\ c$, $o\ d$, &c., Fig. 3, plate 88.

So that we have both a geometrical and an arithmetical rule for drawing the reciprocal spiral.

It may be here observed that this spiral is the only one that can be employed in forming the volutes of the Corinthian capital.

Fig. 3, plate 90, exhibits the scroll with the scale drawn on the first radius.

Plate 91.

To describe the face and falling mould for preparing the scroll.

Let $a\ b$ be the first quarter of the scroll, c the centre; draw $d\ e$ parallel to $b\ c$, touching the outer spiral at d; draw c G parallel to $c\ a$, and through a draw F G parallel to $c\ b$; make G F equal to the breadth of a step; draw F H perpendicular to G H; make F H equal to the height of a step, and join H G; then G H is the pitch line of the stair. Draw lines parallel to $a\ c$, cutting the inner edge of the scroll at the points f, g, h, the outer edge at i, k, l, m, n, the straight line F G in the points n, o, p, q, r, and H G at the points N, O, P, Q, R; let $a\ c$ cut the concave side of the scroll at t, and let it be produced to cut H G at A; from the point h, where the line $d\ c$ cuts the concave spiral of the scroll, draw h W parallel to $a\ c$, cutting A G at W, F G at v, and the convex spiral at u. Draw W H and G E perpendicular to H G.

Make W H and G E each equal to $v\ h$ or G c, and join H E; through the points N, O, P, Q, R, draw lines perpendicular to H G; in the perpendiculars make A T, N F, O G, each respectively equal to a, t, n, f, o, g; also, make N I, O K, P L, Q M, R N, each respectively to $n\ i$, $o\ k$, $p\ l$, $q\ m$, $r\ n$; draw T X parallel to H G, and draw the curves T F G H

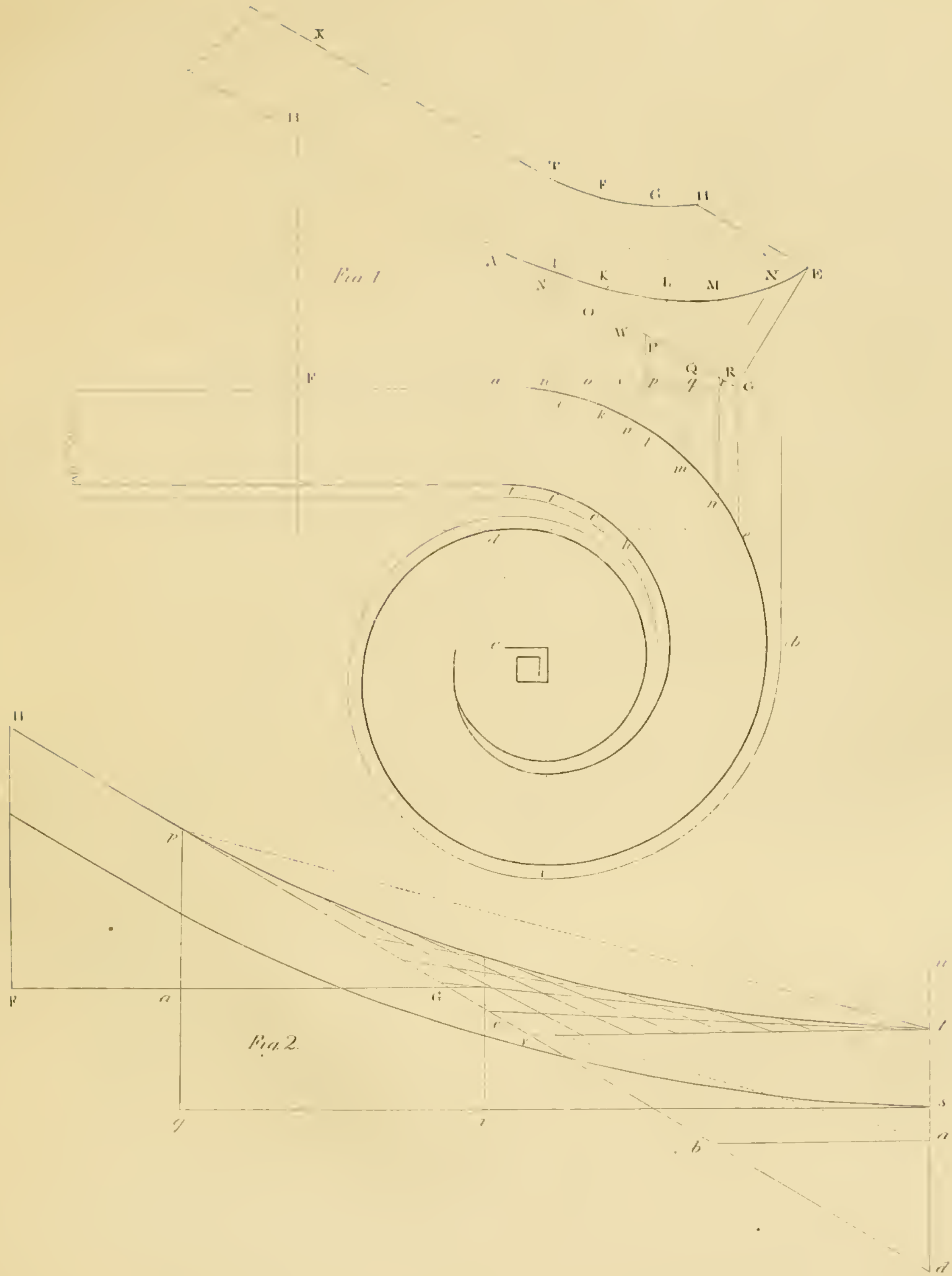


Fig. 1

Fig. 2.

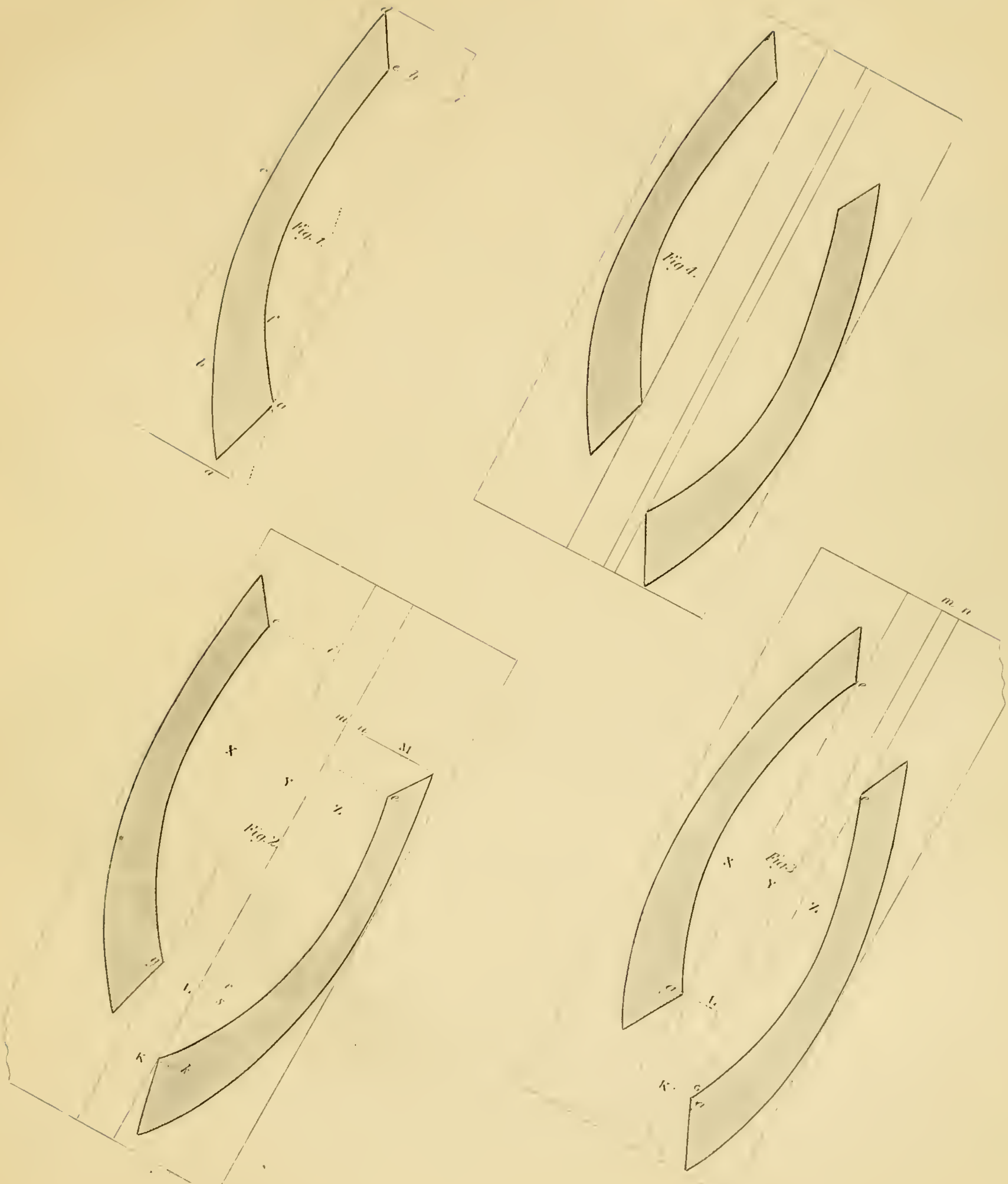


Fig. 1.
Fig. 4.
Fig. 2.
Fig. 3.
X
Y
Z
M
m n
K
k

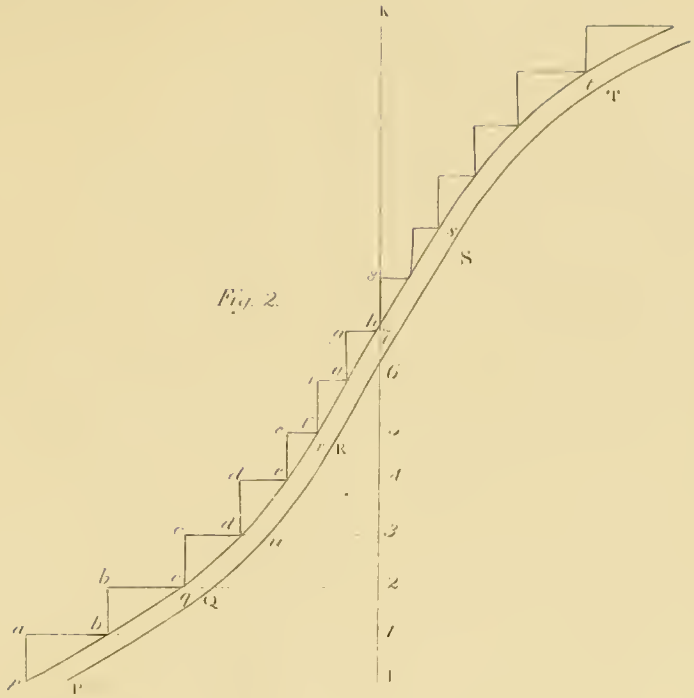


Fig. 2.

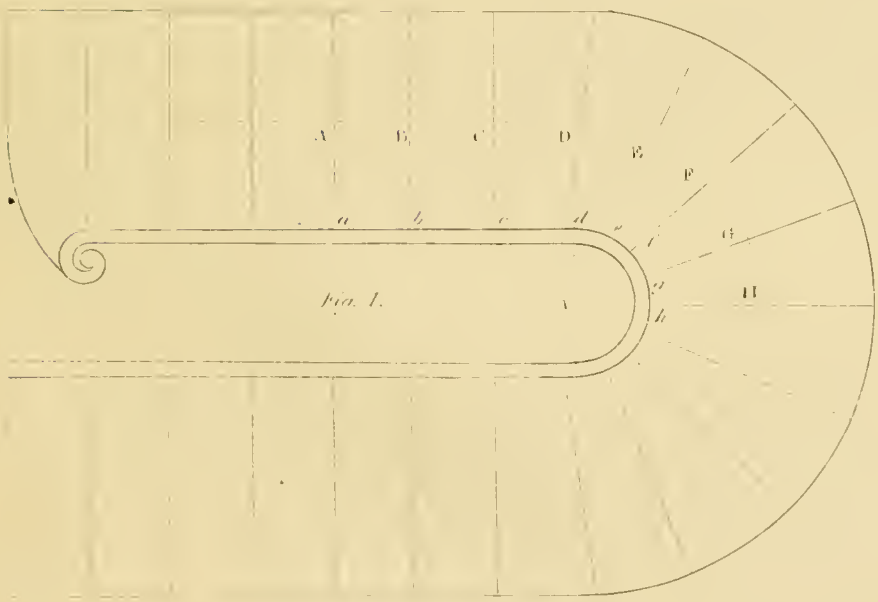


Fig. 1.

and A I K L M N E, which will complete the face mould for the twisted part of the scroll, which is to be glued to the other part formed in one level piece.

The falling mould is constructed as follows: Fig. 2. Let F G H be the pitch board, as in Fig. 1. Divide F G into eight equal parts, and make F *a* equal to three of the parts; through *a* draw *d q* perpendicular to F G, cutting H G at *p*; produce H G to *d*; draw any line *q s* parallel to F G, and make *q s* equal to the stretch out of the first two quarters, *a*, *b*, *v*, of the outward spiral, Fig. 1; through *s* draw *u d* parallel to H F; in H *d* take any distance *d b*, and draw *b a* parallel to F G, cutting *u d* at *a*. Again: in H *d* take *b c* equal to *b a*, and join *c a*; through *p* draw *p t* parallel to *c a*, cutting *u b* in *t*; draw *t v* parallel to F G, cutting H *d* at *v*; then will *v t* be equal to *v p*; divide *v p* and *v t* each into the same number of equal parts, and draw the intersecting lines to the points of division, and the curves formed will be the upper edge of the falling mould; the other edge will be formed by gauging off the thickness of the rail.

Plate 92.

APPLICATION OF THE FACE MOULD TO THE PLANK.

To form the figure of the face mould upon each side of the plank, so that, when the superfluous wood is cut away, the carved surfaces formed thereby may stand perpendicular to the plan, supposing the piece thus formed set in due position.

Let *a b c d e f g* be the Fig. 1 of the face mould, placed in due position to the pitch line *g i*, as when traced from the plan; and let Fig. 2 represent a development of the plank where X represents the top, Y the edge, and Z the under side of the plank.

The face mould is first applied to the top X, so that the points *g* and the chord line *g e* of the mould may make the same angle at *g* with the arris line *g e* of the plank that the figure of the mould at Fig. 1 makes with the pitch line; draw *g* K, making the same angle with *i g* that the pitch line makes with any connecting line or perpendicular, and draw the figure of the mould on the plank; apply the same mould to the other side Z of the plank to the point K, so that the chord may make the same angle with the other arris as on the first side, and draw the figure of the mould on this last side; then the solid which is formed by cutting away the superfluous wood is the piece required.

But as it may be desirable to apply the tips of the mould *g* and *e* close to the edge of the plank, Fig. 3 shows how the plank is to be lined out according to this application. Here the pitch line *g* K makes the same angle with the upper arris of the plank as before; draw *g* L perpendicular to either arris, cutting the lower arris at L; make the angle K L G equal to the angle *e g i*, Fig. 1; make L *g* equal to L K, and draw the chord *g e*, in the plane Z, parallel to the arris line; in the plane Z apply the tips *g* and *e* of the face mould to the line *g e*, as exhibited in the figure; then draw the form of the face mould as before.

DEMONSTRATION.

Fig. 2. Draw *g* L in the plane Y, cutting the lower arris of the plank at L; draw the chord K *e* of the face mould in the plane Z, and draw L M in the same plane parallel to K *e*; also draw L *s* perpendicular to K *e*, cutting K *e* at *s*. Now, imagine the figure M L K *e* to be moved so as to revolve on the point L, until L M come into the arris L *m*; it is evident that the point K will move in the circumference of the circle K *k*, and will come into the position *k*; and that the angle K L *k* will be equal to the angle *m* L M; but the angle *m* L M is equal to the angle *a g i*, Fig. 1. Again: reverting to Figs. 2 and 3, it is plain in Fig. 3, that if the angle K L *g* in the plane Z be made equal to the angle *e g i*, Fig. 1, and if L *g* be made equal to L K, and the mould applied to each side of the plank as in the figure, the solid, when cut out, by taking away the superfluous wood, will be equal and similar in all its corresponding parts to that cut out according to the oblique chords, Fig. 2.

Fig. 4 shows another application where the chord of the face mould is neither applied to the angle *e g i*, nor parallel to the arris lines; but as this application is rather curious than useful, the bare inspection of the diagram will render it sufficiently clear to those who will take the trouble to consider it.

Plate 93.

ON THE FORMATION OF THE STRING.

PROBLEM.

To form the soffit of a stair with easings at the junctions of the fliers and winders.

Let Fig. 1 be the plan of the stair, the breadth of

the steps being divided equally along the middle line. Suppose the winders to begin at riser C, and let the string from the riser of the curtail step to the point C be straight.

The first thing to be done is to stretch out the string; but in this development it will not be necessary to exhibit it entirely, the circular part and a small portion of the straight part at each end will be sufficient; therefore, beginning at A, we shall take in the two fliers over A B and B C.

In Fig. 2, draw p I parallel to the rail, and make p I equal to the length of the line $a\ b\ c\ d\ e\ f\ g\ h$. Draw I K perpendicular to p I, make I 1; 1, 2; 2, 3; equal to the heights of the three risers over A B C, Fig. 1; also, in Fig. 2, make 3, 4; 4, 5; 5, 6; 6, 7; 7, 8; each equal to the height of the winders over D, E, F, G, H. In the plan Fig. 1, suppose a line drawn through the centre x perpendicular to the rail, cutting the middle line at D, and let this line be produced to u, Fig. 2; in Fig. 2, draw 3 c parallel to p I, cutting $x\ u$ at u; join $u\ p$ and u 7; draw $p\ a$ in the same straight line with the riser A, $b\ b$ in the same straight line with the riser B, and $c\ c$ in the same straight line with the riser C, to cut $p\ u$ at b and q; make $u\ r$ equal to $u\ q$, then form the easing curve $q\ r$; draw 3 c, 4 d, 5 e, 6 f, 7 g, parallel to p I, cutting the easing curve at d and e, and u 7 at f and g; draw $d\ d$, $e\ e$, $f\ f$, $g\ g$, parallel to I K; make $c\ d$ equal to $c\ d$, $d\ c$ equal to $d\ c$, $e\ f$ equal to $e\ f$, $f\ g$ equal to $f\ g$, and $g\ h$ equal to $g\ h$; then D H being divided into equal parts at the points E, F, G, join D d, E e, F f, G g, and produce them to the wall line; in Fig. 2, draw the curve P Q R parallel to $p\ q\ r$ at a proper distance, which completes one half of the string. The manner of completing the other half is evident.

OBSERVATIONS.

Having given the details of finishing, I shall now proceed to offer a few general remarks in relation to this subject.

The selecting of building materials has not, in general, received that care and attention which this important subject demands. Many buildings have been ruined, the owners of others have been displeased, and not without just cause; and the workman has lost his reputation, and forfeited his claim to public patronage, solely from neglect in this important particular.

The first care of a master builder should be to see that his lumber is properly seasoned. The best method of seasoning is, after boards or plank have been sawed at the mills, they should be immersed in salt or fresh water for the space of one or two months; larger lumber should remain in this situation till the sap is properly extracted from the wood; this operation preserves the lumber in some degree from the dry rot. Next take the boards or plank out of the water, and pile them in a situation where the air may have a free circulation through and on all sides of the piles. They should remain in this situation for one year; then take them down and select such as are suitable for finishing: these should again be stuck in a building, or covered in such a manner as to be secure from the weather; they should remain in this situation at least six months before they are used. While preparing the stuff for finishing, it should be spread to the sun every fair day, and put under cover at night for three or four weeks before it is put together. The mechanic will feel himself well paid for his time and trouble when he shall examine his work at any subsequent period.

Framing timber should be squared up soon after being taken out of the water, and stuck up under cover for the space of six months before it is worked into buildings; this will correct the erroneous idea, in many cases, where the settling of the floor has been attributed to bad workmanship, when, in fact, it has been occasioned by the shrinking of the timber.

The kind of lumber in general use for building in the New England States is white, yellow, pitch, and Norway pine; spruce, cedar, and sometimes hemlock, white and basswood. The hard woods are oak, mahogany, maple, cherry, and ash. In the Southern States there is found a superior species of pine, which, for durability, is preferable to northern pine, when used for floor boards or joists.

Pine boards and joists are sorted into different qualities, known as Nos. 1, 2, and 3. No. 1 is square edged, free from knots, shakes, and rot. No. 2, the second quality, is sound, not entirely free from knots, and is square edged. No. 3 has knots, shakes, is wane edged, and has some rot. No. 1 is used for the best of finishing; No. 2 for rough boarding, such as roofs, side and end boarding, &c., where the edges are required to be tongued and grooved, or rabbeted. From this quality, by properly sorting them, good floor boards may be selected, which should be sawed from four to seven inches wide; many of them will be clear, and, after they are wrought to a thickness, the clearest may be used for the best rooms, and the others as they may be suitable for the different rooms.

By Ithiel Town.

Fig. 1.

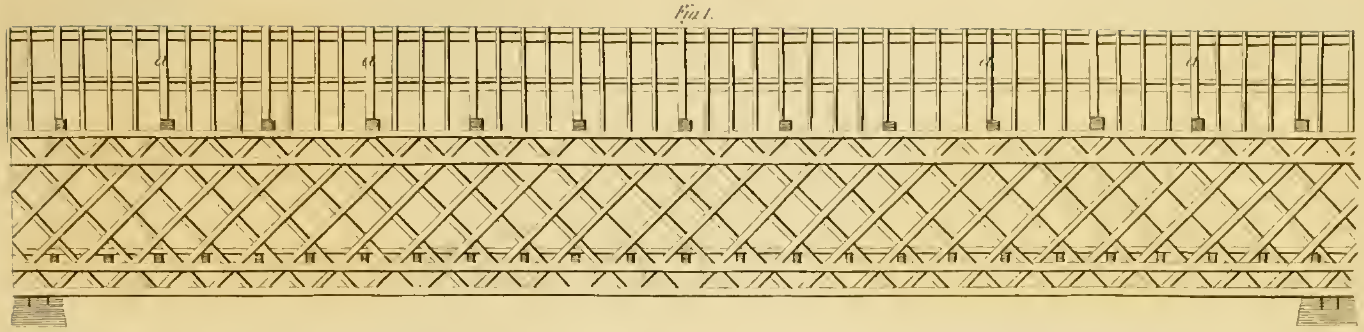


Fig. 2.

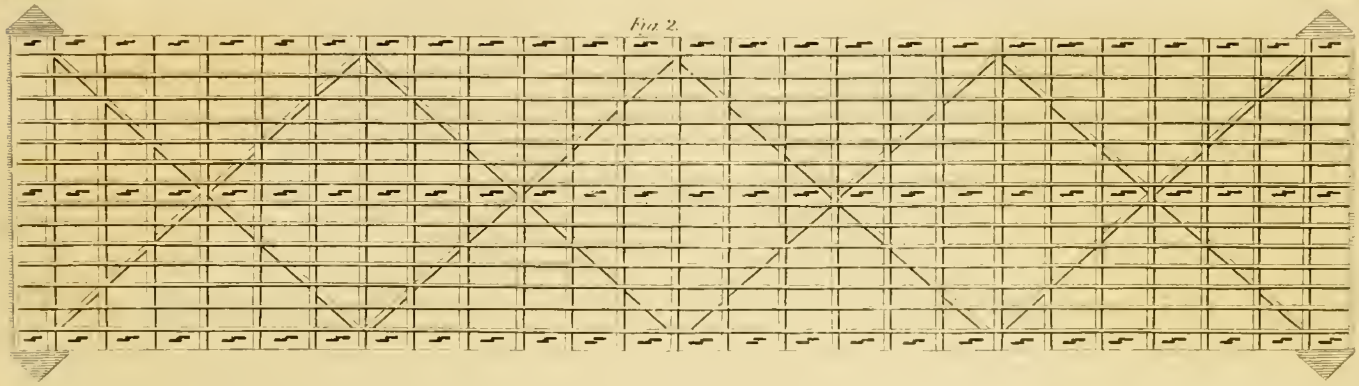


Fig. 4.

Fig. 3.

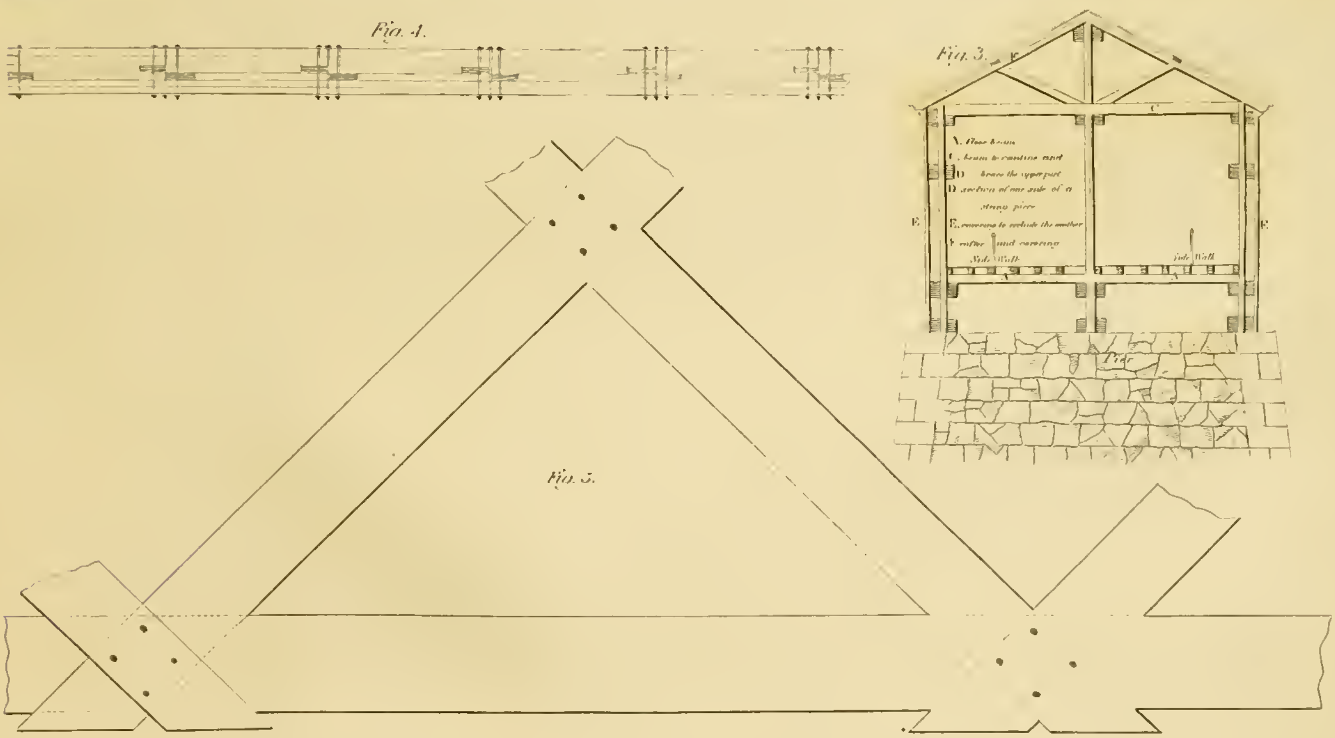


Fig. 5.

BRIDGES.

Mr. Ithiel Town's improvement in the construction of bridges being considered preferable to any mode of bridge building yet laid before the public, it has been thought best, in this department of the work, to give his arguments and description in his own words, and to refer the reader to the introduction for such additional facts and remarks as has been thought necessary to lay before him, in order to give him a more perfect understanding of this important branch of his profession.

Plate 94

A Description of Ithiel Town's Improvement in the Construction of wooden and iron Bridges, intended as a general System of Bridge Building for Rivers, Creeks, and Harbors, of whatever Kind of Bottoms, and for any practicable Width of Span or Opening, in every Part of the Country.

To establish a general mode of constructing wooden and iron bridges, and which mode of construction shall, at the same time, be the most simple, permanent, and economical, both in erecting and repairing, has been for a long time a desideratum of great importance to a country so extensive, and interspersed with so many wild and majestic rivers as ours is. It has been too much the custom for architects and builders to pile together materials, each according to his own ideas of the scientific principles and practice of bridge building, and the result has been, first, that nearly as many modes of construction have been adopted as there have been bridges built; second, that many have answered no purpose at all, and others but very poorly and for a short time; while most of the best ones have cost a sum which deters and puts it out of the power of probably five sixths of those interested in ferries to substitute bridges which would obviate the many dangers and delays incident to them.

That architects and builders adhere to their own ideas in the construction not only of bridges, but of buildings, is most universally true. They are obstinately opposed to the adoption of any other mode than their own; consequently it is true, and it is seen to be so throughout the country, (and it is much to be regretted,) that in very few instances, either in erecting bridges or buildings, there is any model,

either uniform or in general, very good. But in bridges and public buildings, it would seem something better might be expected if men scientifically and practically acquainted with such subjects would step forward in a disinterested manner, and determine between principles which are philosophical and those which are not, and between modes of execution which are founded in practice and experience and those which are founded in ignorance and inexperience; and in matters of taste, if they would determine in favor of classic and well-established usage, and not that which is the offspring of unimproved minds and whimsical fancies, which are ever upon the rack to establish new things — the creation of their own imaginations, and which are, therefore, sure to be wrong, for this good reason — that their authors are so.

Perhaps the following proposition comprises what is the most important to be determined with regard to a general system of bridge building, viz.: —

By what construction or arrangement will the least quantity of materials and cost of labor erect a bridge of any practicable span or opening between piers or abutments, to be the strongest and most permanent, and to admit of the easiest repair.

In giving the best answer to this proposition which I am capable of after a number of years' attention to the theory and practice of this subject, I shall refer to plate 94. The mode of construction is so simple and plain to inspection as to require little explanation of it.

Fig. 3 is an elevation of one of the trusses of a bridge; one, two, or three of those trusses placed vertically upon piers are to be considered as the support of the bridge, and are to be of a height, at least, sufficient to admit a wagon to pass under the upper beams which lie horizontally upon the top string piece of the side trusses; and on these same side string pieces rest the feet of rafters, which form a roof to shingle upon. In this case a middle truss is used, which will always be necessary in bridges of considerable width. The height of it will be as much greater than the side ones as the height or pitch of the roof. The height of the trusses must

be equal to the whole height of the bridge required, and is to be an exact continuation of the work represented in Fig. 1.

The height of the trusses is to be proportioned to the width of the openings between the piers or abutments, and may be about one tenth of the openings, when the piers are fifteen feet or more apart — a less span requiring about the same height, for the reasons before stated.

The diagonal bearing of these trusses is composed of sawed plank, ten or eleven inches wide, and from three to three and a half inches thick. It may be sawed from any timber that will last well when kept dry. White pine and spruce are probably the best kinds of timber for the purpose, on account of their lightness, and their not being so subject to spring or warp as white oak.

The nearer those braces are placed to each other, the more strength will the truss have, and in no case are they to be halved or gained where they intersect each other; but they are to stand in close contact, depending entirely on three or four trunnels which go through each joint or intersection; and where the string pieces pass over these joints, the trunnels go through them also, and are each of them wedged at each end to keep the timber in close contact. A chain or clamp is necessary to bring the work tight together.

Trunnels may be made of white oak, one and a half inches in diameter. They are made very cheaply and excellently by being rived out square, and driven, while green or wet, through a tube fitted to a block, and ground to an edge at the top end. They are then to be seasoned before they are used.

The string pieces are composed of two thicknesses of plank, of about the same dimensions as the braces, and they are so put together as to break joints, as shown at Fig. 4. This renders long-hewn timber unnecessary, as also any labor in making splices and putting on iron work.

For any span or opening not exceeding one hundred and thirty feet, one string piece at top and one at bottom of each truss, if of a good proportion and well secured, will be sufficient; but as the span is extended beyond one hundred and thirty feet, two or more at top and bottom would be required, as shown in Fig. 1, where two string pieces run over the two upper and lower series of joists or intersections of the braces: and in wide spans the floor beams may be placed on the second string piece, as shown at Fig. 1.

Fig. 5 shows, on a larger scale, how each joint is secured, by which it is seen that the trunnels take hold of the whole thickness of each piece.

Fig. 4 is a section of a bridge of this construction, and shows the manner in which the braces and string pieces come together, and also the manner of making the floor of the bridge, and of butting beams and braces over head, which are to be connected with the middle truss for the purpose of bracing the bridge against lateral rack or motion. Very flat-pitched roofs will be preferable, as they will, in that case, be a greater support to the upper part of the bridge.

a a a a, Fig. 1, show the elevation of the roof.

Fig. 2 is the floor or plan of the bridge, showing the mode of bracing and the floor joist.

Fig. 4 is a view of the bottom or top edge of the string piece, and shows how the joints are broken in using the plank, and also how the trunnels are disturbed.

This mode of construction will have the same advantages in iron as in wood, and some in cast iron which wood has not, viz., that of reducing the braces in size between the joints, and of casting flaunches to them where they intersect, thereby making it unnecessary to have more than one bolt and nut to each joint or intersection.

When it is considered that bridges, covered from the weather, will last seven or eight times as long as those not covered, and that the cheapness of this mode will admit of its being generally adopted, with openings or spans between piers composed of piles, and at a distance of one hundred and twenty to one hundred and sixty feet apart, then the construction of long bridges over mud-bottomed rivers, like those at Washington, Boston, Norfolk, Charleston, &c., will be perceived to be of great importance, especially as the common mode of piling is so exposed to freshets, uncommon tides, driftwood, and ice, as not to insure safety or economy in covering them, and, consequently, continual repairs, and often rebuilding them, become necessary. There is very little, if any, doubt that one half of the expense, computing stock and interest, that would be required to keep up, for one hundred years, one of the common pile bridges, like those at Boston, would be sufficient to maintain one built in this new mode, keep it covered, and have all

or nearly all, the piers built with stone at the end of the one hundred years. If this be the case, it would be great economy to commence rebuilding, by degrees, in this manner. The saving in the one article of floor planks, if kept dry, would be very great, as, by being so much wet, they rot and wear out in about half the time.

For aqueduct bridges of wood or iron, no other mode can be as cheap or answer as well. This mode has equal advantages also in supporting wide roofs of buildings, centres of wide arches in masonry, trussed floorings, partitions, sides of wood towers, steeples, &c., &c., of public buildings, as it requires nothing more than common planks, instead of long timber — being much cheaper, easier to raise, less subject to wet or dry rot, and requiring no iron work.

Some of the advantages of constructing bridges according to this mode are the following: —

1. There is no pressure against abutments or piers, as arched bridges have, and, consequently, perpendicular supports only are necessary: this saving in wide arches is very great, sometimes equal to a third part of the whole expense of the bridge.

2. The shrinking of timber has little or no effect, as the strain upon each plank of the trusses, both of the braces and string pieces, is an end-grain strain or lengthwise of the wood.

3. Suitable timber can be easily procured and sawed at common mills, as it requires no large or long timber; defects in timber may be discovered, and wet and dry rot prevented, much more easily than could be in large timber.

4. There is no iron work required, — which, at best, is not safe, — especially in frosty weather.

5. It has less motion than is common in bridges, and which is so injurious and frequently fatal to bridges; and, being in a horizontal line, is much less operated upon by winds.

6. A level road way is among the most important advantages of this mode of construction.

7. The side trusses serve as a frame to cover upon, and thereby save any extra weight of timber, except the covering itself; and the importance and economy of covering bridges from the weather is too well understood to need recommendation after the experience which this country has already had.

8. Draws for shipping to pass through may with perfect safety be introduced in any part of the bridge without weakening, as in arched bridges, where the strength and safety of the arches depend so much on their pressure against each other and abutments, that a draw, by destroying the connection, weakens the whole superstructure.

9. The great number of nearly equal parts or joints into which the strain, occasioned by a great weight upon the bridge, is divided, is a very important advantage over any other mode, as, by dividing the strain or stress into so many parts, that which falls upon any one part or joint is easily sustained by it without either the mode of securing the joints, or the strength of the materials being sufficient.

10. The expense of the superstructure of a bridge would not be more than from one half to two thirds of other modes of constructing one over the same span or opening. This is a very important consideration, especially in the Southern and Western States, where there are many wide rivers, and a very scattered population to defray the expenses of bridges.

11. This mode of securing the braces by so many trunnels gives them much more strength when they are in tension strain than could be had in the common mode of securing them by means of tenons and mortises; for tenons being short, and not very thick, compared with this mode, nor having so much hold of the pins or trunnels as in this case, will, of course, have much less power to sustain a tension or pulling strain; and it is obvious that this strain is in many cases equal to, and in others greater than, the thrust or pushing strain. It is also very obvious that this pushing or thrust strain in the mode of tenons and mortises receives very little additional strength from the shoulders of the tenons, as the shrinkage of the timber into which the tenon goes is generally so much as to let the work settle so far as to give a motion or vibration, which, in time, renders them weak and insufficient.

12. Should any kind of arched bridge, for any reason, be preferred, however, it may be arched either at top or bottom, or both; still this same mode of combining the materials will have all the advantages, as to cheapness and strength, over the common ones of framing, as in the case of the horizontal or straight ones before described. In cases where abutments are already built, it may sometimes be preferred.

Sidewalks may with equal ease be constructed, either on the outside or inside of the main body of

the bridge, which particular, as also the great strength of the mode, &c., may be better seen by examination of the models, which are, or soon will be, placed in most of the principal cities of the United States; and no merit is either desired or claimed in this new mode of construction by the patentee which the mode itself does not command, even on the most strict philosophical investigation, as to its mathematical principles, the easy, practicable, and advantageous application of materials, the advantages it possesses in mechanical execution, and its simplicity, strength, economy, and durability, as a general and uniform mode of bridge building.

Science and practice will, in a short time, decide on this question, so important to this extensive country.

I shall conclude this article by a few ideas taken from the celebrated Robert Fulton's Treatise on Canal Navigation, page 117 and subsequent pages.

In England, the attention of engineers has, of late years, been much engaged on bridges of iron. These bridges, as experience produces courage, are progressively enlarging their dimensions; nor should I be surprised if genius should, in time, produce the mechanic rainbow of one thousand feet over wide and rapid rivers. In crossing the rivers in such countries as Russia and America, an extensive arch seems to be a consideration of the first importance, as the rivers, or even rivulets, in time of rain, suddenly swell to a great height; and in the spring, on breaking up of ice, the immense quantity which is borne down with a rapid stream would, if interrupted by small arches and piers, collect to such a weight as ultimately to bear away the whole. It is, therefore, necessary that, in such situations, an arch should be extended as far as possible, and so high as to suffer every thing to pass through, or the inhabitants must, without some other expedient, submit their passage to the casualties of the weather.

The important objection to bridges of wood is their rapid decay; and this objection is certainly well founded when particular situations are alluded to where timber is scarce, and, consequently, expensive. But in such countries as America, where wood is abundant, I conceive it will be a fair criterion to judge of their application by calculating on the expense of a bridge of stone and one of wood, and then compare the interest of the principal saved in adopting the wood bridge with the expense of its annual repairs.

I have before exhibited the necessity of constructing bridges in America of an extensive span or arch, in order to suffer the ice and collected waters to pass without interruption; and for this purpose, it must be observed that a wood arch may be formed of a much greater length or span than it is possible to erect one of stone: hence wooden bridges are applicable to many situations where accumulated waters, bearing down trees and fields of ice, would tear a bridge of stone from its foundation.

It therefore becomes of importance to render bridges of wood as permanent as the nature of the material will admit.

Hitherto, in bridges not covered from the weather, the immense quantity of mortises and tenons, which, however well done, will admit air and wet, and, consequently, tend to expedite the decay of the weak parts, has been a material error in constructing bridges of wood.

But to render wood bridges of much more importance than they have hitherto been considered — first, from their extensive span; secondly, from their durability — two things must be considered: first, that the wood works should stand clear of the stream in every part, by which it never would have any other weight to sustain than that of the usual carriages; secondly, that it will be so combined as to exclude, as much as possible, the air and rain.

When the true principle of building bridges of wood is discovered, their progressive extension is as reasonable as the increased dimensions of shipping, which, in early ages, was deemed a great work, if they amounted to one hundred tons' burden; but time and experience have extended the art of ship building to two thousand tons, and in the combination and arrangement of the various and complicated parts there certainly is more genius and labor required than in erecting a bridge of five hundred or one thousand feet span. But the great demand for shipping has rendered their formation familiar, and their increased bulk has gradually grown upon our senses. But had a man, in the infancy of naval architecture, hinted at a vessel of two thousand tons, I am inclined to think his contemporary artists would have branded him as a madman.

Section, shewing the construction of the Arches, the Centering &c

Fig. 1

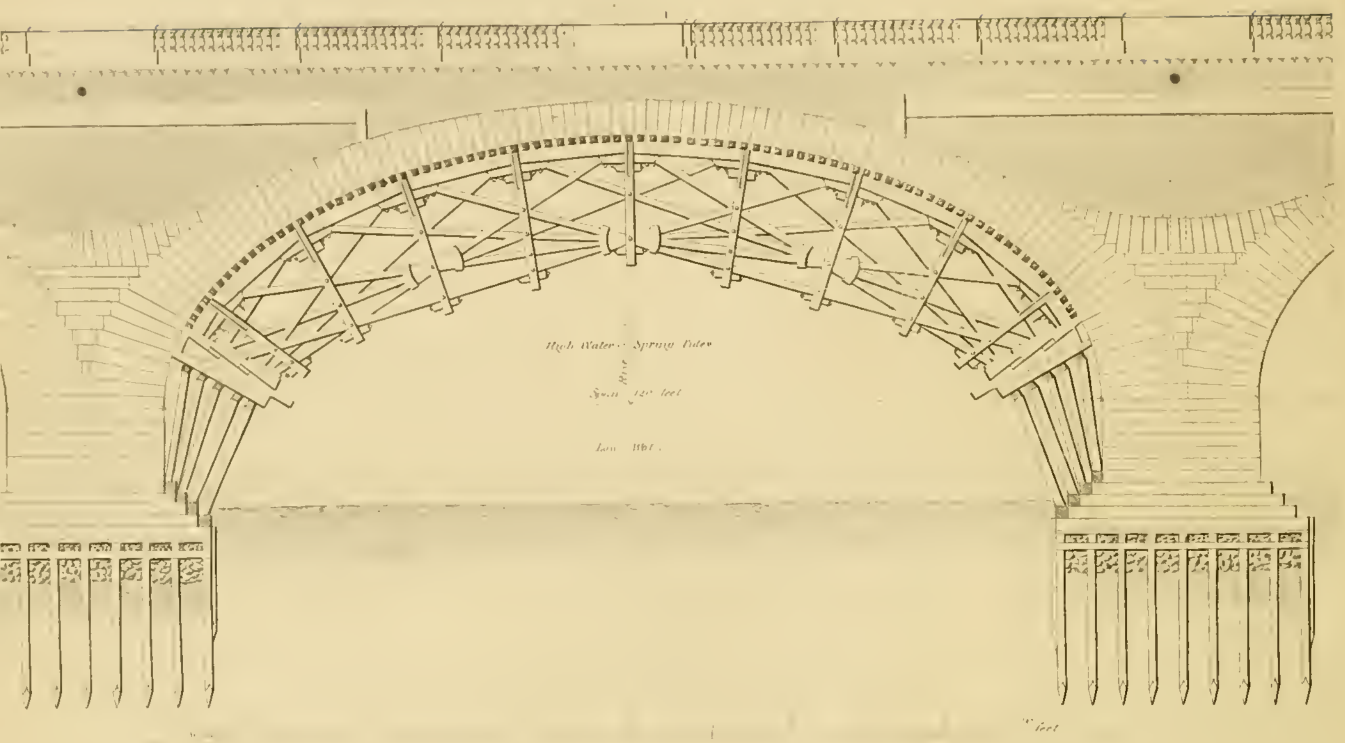
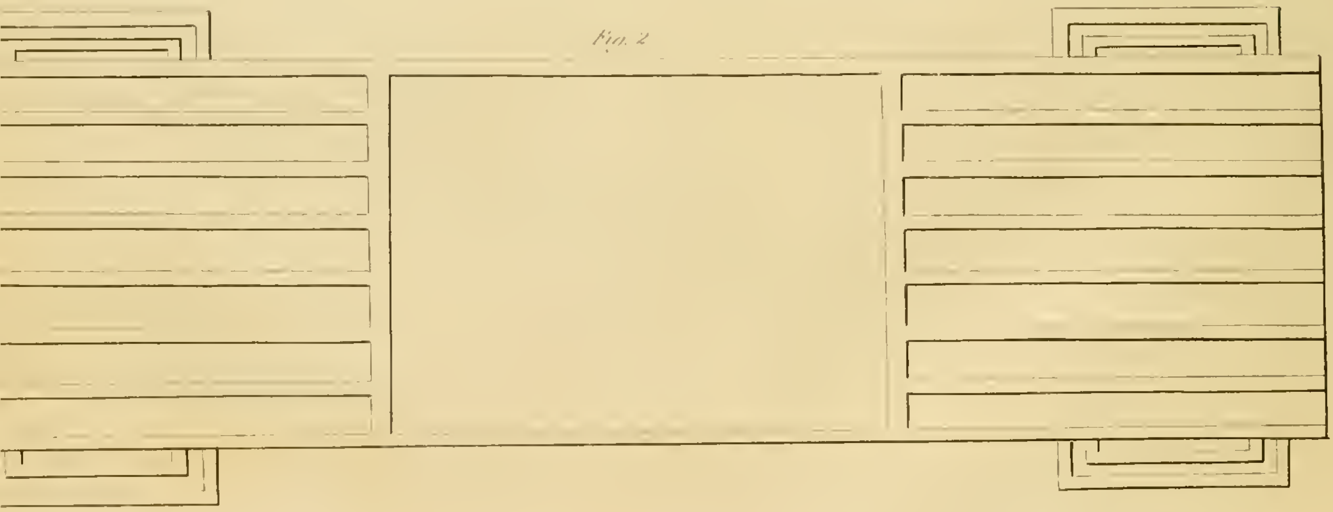


Fig. 2



WATERLOO BRIDGE.

Plate 95.

This bridge, thrown over the River Thames, at London, was projected by Mr. George Dodd, about the year 1805. Considerable time, however, elapsed before the ultimate arrangements necessary to carry it into execution were made. The first act was obtained in the month of June, 1809, and incorporated the proprietors under the name of the "Strand Bridge Company," empowering them to raise the sum of £500,000 in transferrable shares of £100 each; and the further sum of £300,000, by the issuing new shares, or by mortgage, in case it should be found necessary. In July, 1813, a second act was passed, enabling them to raise an additional sum of £200,000; and in July, 1816, a third act was obtained, granting the company further powers, and changing the name from Strand Bridge to Waterloo Bridge, which name it now bears.

Mr. Rennie, having been appointed engineer to the company on the 23d day of June, 1810, furnished two designs, one of seven and the other of nine arches, the latter of which was finally approved by the committee and ordered to be put in execution.

This noble bridge is situated about half way between the Bridges of Blackfriars and Westminster. The river at this place is about 1326 feet wide at high water; and ordinary spring tides rise abont 13 feet, and ordinary neap tides about 9 feet 6 inches. The greatest depth at low water is about 9 feet. The bed of the river is composed principally of a stratum of sand and gravel resting upon clay.

The bridge is level, and consists of nine semi-elliptical arches, each having a span of 120 feet, and a rise of 35 feet; thus leaving for the navigation 30 feet of clear height above the high water of spring tides, and forming an ample water way of 1080 feet. The abutments are 40 feet thick at the bases, and diminish to 30 feet at the springing of the arches. Their lengths, including the stairs, are 140 feet. The piers are 30 feet broad at the base, and diminish to two thirds at the springing of the arches. Their lengths at the bases are 87 feet. The points or salient angles of the piers are in the form of a Gothic arch, and are terminated above by two three-quarter columns, supporting an entablature which forms a recess. The whole is surmounted with a balustrade and a frieze and cornice of the Grecian Doric. The columns are Doric also, and were selected on account of the extraordinary strength of their proportions, as being best suited to a structure of this magnitude: they are 23 feet 9 inches high, or, rather, more than four diameters.

The clear width between the parapets is 42 feet 4 inches, allowing 28 feet 4 inches for the carriage-way, and 7 feet for each of the footpaths.

Four plying places, or stairs, for watermen, are formed by circular wings, projecting at right angles to the bridge, with archways leading to the road way. These wings are ornamented with columns, entablatures, &c., as before described.

The bridge being level, and of so great a length, it became necessary to provide means for carrying off the rain water. This is effected by having circular openings in the centre of each pier, which enter the river immediately below low-water mark; these openings are connected with iron branch pipes up to the level of the road-way, where gratings are placed to receive the water.

The roads, or approaches, to each end of the pier are 70 feet wide throughout, except just at the entrance into the Strand, and are carried over a series of semicircular brick arches of 16 feet span each. The Surry, or southern approach, is formed by 39 of these, besides an elliptical arch of 26 feet span over the narrow wall road, and a small embankment about 165 yards long, having an easy and gradual ascent of not more than 1 foot in 34 feet.

	Feet.
The length of the brick arches in the Surry approach is	766
Ditto of those in the Strand approach, . .	310
Total length of the bridge from the ends of the abutments, ...	1380
Total length of the bridge and brick arches,	2456

Fig. 1 exhibits a longitudinal section of one of the arches, the adjacent piers, and part of the next adjacent arches, with the elevation of one of the trusses forming the centre. The curve of equilibrium passes through the middle of the length of the arch stones, or very nearly so. The hollows over the piers are raised to the level of the summits of the arches by parallel brick walls, and connected with blocks of stone from wall to wall, for supporting the road-way.

The centring was composed of eight trusses. It is 1250 feet long, has nine elliptical arches of 120 feet

span over the river, with piers 20 feet thick, built entirely of granite, and forty brick arches for a causeway on the Surry side. This plate is given with a view of showing the construction of masonry, as generally applied to bridge building. The geometrical principle of constructing arches, and drawing the joint lines so as to be perpendicular to the curve, is sufficiently explained in plate 101.

Fig. 2. The horizontal section showing the brick walls, as *a*, *a*, &c., which are covered with stone; also, the foundation of the piers at *b*, *b*, &c.

RURAL VILLA AT MILFORD, MASS.

Plate 96.

On this plate we have given a front elevation, with a transverse section, together with the entrance and chamber-story plans of a villa that we have erected during the past year, in the town of Milford, Mass., for A. C. Mayhew, Esq. It was our intention at first to place at the last part of this work a series of six designs for buildings of this character, with their plans and details; but upon further consideration we have concluded to omit them, and, at some future time, publish them in a form more in keeping with a work of a rural character; this plate, however, being made, we have inserted it as plate 96. The size of the building will be readily seen by the figures on the drawing. The outside walls are of hard-burnt bricks, and are twelve inches in thickness, which are vaulted, or having an air space of four inches between the exterior and interior courses. The angles of the building are laid solid, as are also the sides of the openings in the walls, such as the sides of the doors, windows, &c. The vaulted portions are connected together by means of ties of brick in every two feet in length. The exterior walls are covered with stucco cement, and colored in imitation of drab stone. The exterior wood work is painted, and sanded with beach sand.—Editors.

CHURCH EDIFICE AT MILFORD, MASS.

Plate 97.

On this plate will be found the two plans, and the front elevation of a small church which was erected under our superintendence in 1850, for the Pearl Street Universalist Society of Milford, Mass. We do not present it as containing any thing of peculiar merit or of costly design; but the arrangement of the plans and the general features of the building having received the approval and approbation of building committees and others interested in such matters, we have, at their urgent solicitations, and at the suggestions of many others, inserted this plate for the benefit of those seeking the information the plate and its description may contain. The following description of this edifice appeared in the Trumpet and Universalist Magazine at the time the building was dedicated; and, with a few slight alterations, we transcribe it entire, as the description of plate 97.*

ARCHITECTURAL DESCRIPTION OF THE NEW MEETING-HOUSE IN MILFORD, MASS.

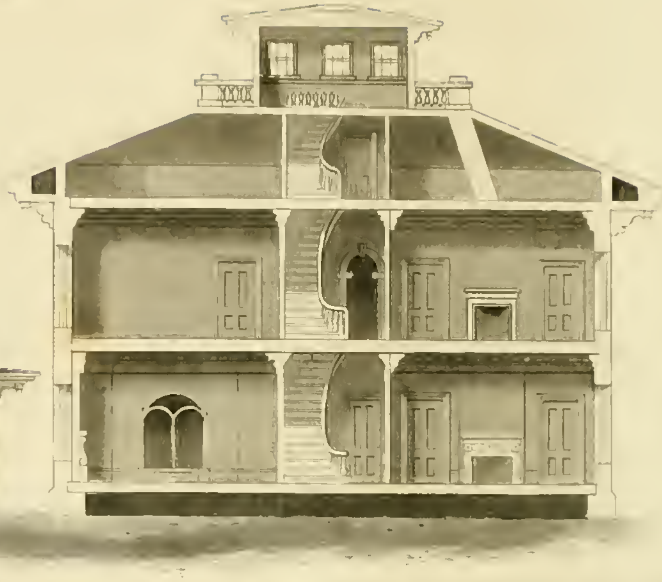
This building is built of wood, erected upon a brick stylobate or basement, and is of the following dimensions, viz., length, 72 feet 8 inches; width, 51 feet, outside; with a projecting vestibule on the front end, 13 feet wide by 26 feet long, and the posts are 25 feet in height. Upon the roof of the vestibule stands a pedestal, 19 feet square and 13 feet high, finished with suitable projections; upon this is a clock tablet, 15 feet square and 12 feet high, covered with a roof showing an entablature and pediment on each side; the tablet is finished with heavy mouldings, and a recess 8 inches deep is made on each side, to receive a dial 7 feet in diameter. Rising from this is an octagonal bell tower, 12 feet in diameter and 16 feet high, including its base and entablature; on each of its sides are arched openings, 3 feet 3 inches in width, and in each of which is a balustrade, composed of heavy-turned balusters. Upon this tower is an octagonal pedestal, 6 feet high and 11 feet in diameter, with deep panels on each side, which is surmounted by a spire 45 feet high, crowned with a carved finial, making the entire height from the line of the grading 136 feet. The style of architecture is the Romanesque, which is a combination of the Roman and the late Norman, the latter being the prevailing style of the 11th century. The corners of the building, together with the vestibule, are finished with heavy pilasters 2 feet 9 inches wide, in each of which is a deep circular-headed panel; upon these rests a dentil corniced entablature, 5 feet deep. The cornice of the entablature is continued up the rakes of the main building and vestibule, which finish gives the whole an imposing and massive appearance.

The building is lighted on either side by three circular-headed windows, which are composed of two circular-headed parts, and separated by a large mullion; and the front of the main building, on either side of the vestibule, by one of the same style, and of two thirds the width

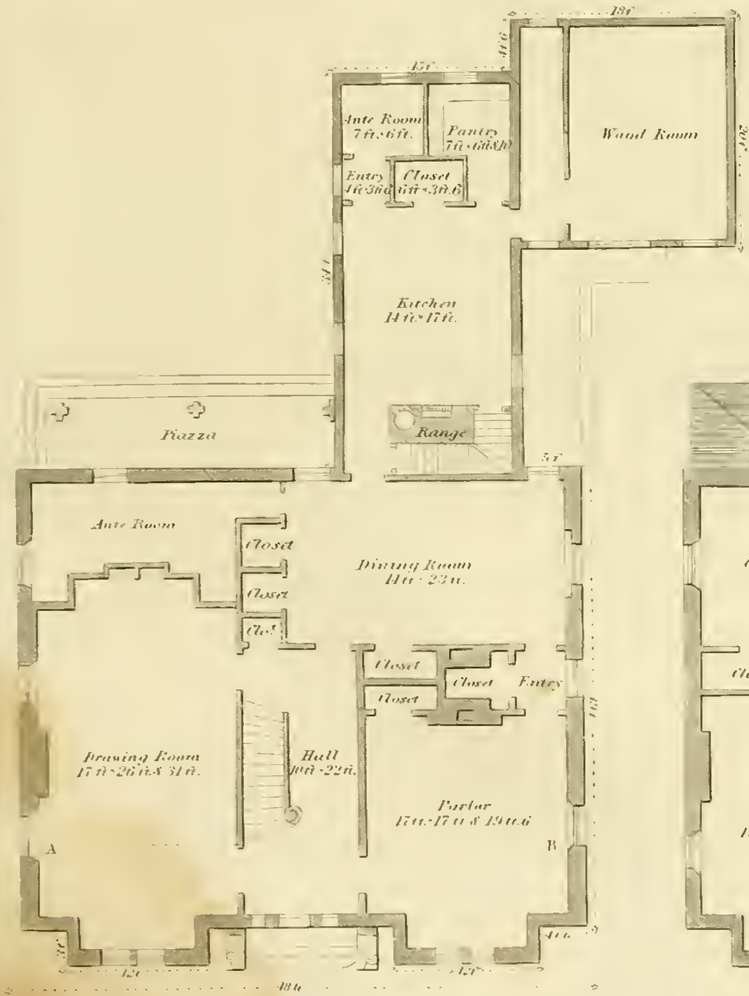
* To our beloved friend, the Rev. Henry A. Eaton, pastor of the society, and under whose ministrations the building was erected, this plate is respectfully dedicated, as a small tribute of respect and esteem, by the architects.

THOMAS W. SILLOWAY,
GEORGE M. HARDING.

Front Elevation

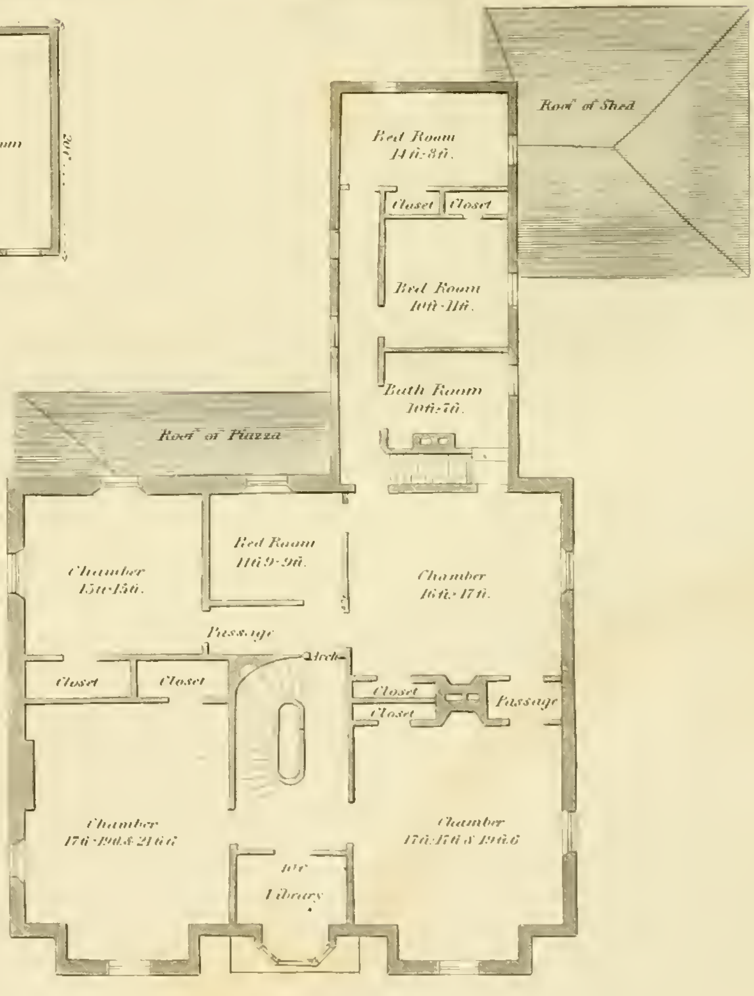


Section on line A.B.

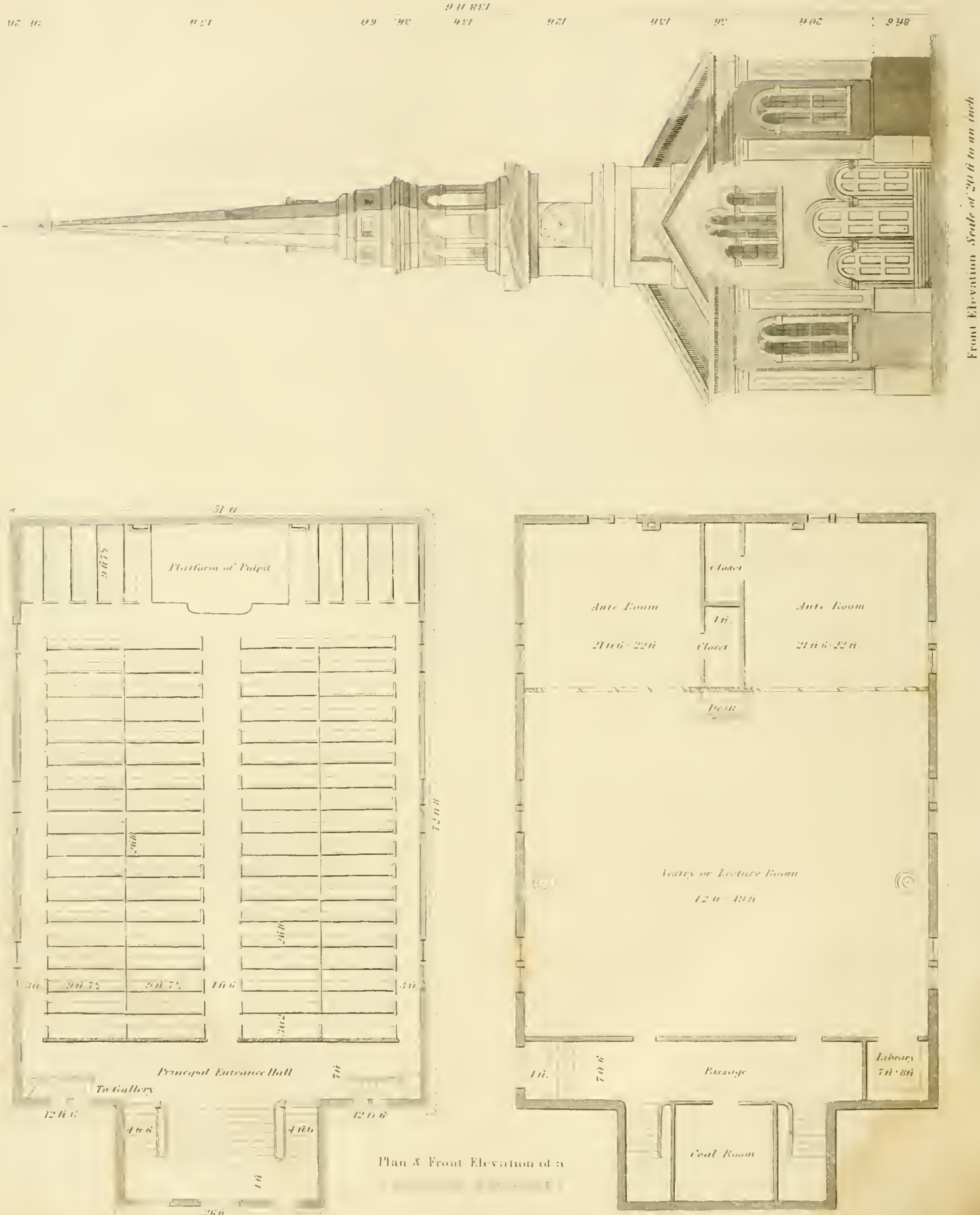


Plan of Entrance Story

Scale of 16 ft. to an inch



Plan of Chamber Story



Plan & Front Elevation of a

Plan of Principal Floor

Scale of 16 ft to an inch

Plan of Vestry Floor

of those on the sides, making them adapted to their location. The choir-room, which is on the second floor of the vestibule, is lighted by a large window, composed of one in its centre, similar to those before described; to which is added on either side another of one half its width, and a proportionate height, and separated from it by pilasters, the capitals of which are so disposed that the centre window is stilted 1 foot 6 inches; the width of the entire window is 11 feet. Beneath this window, on the front of the vestibule, is the main entrance to the building, which is by three circular-headed doors, the centre one of which is 5 feet wide and 13½ feet high; the arch of this door is stilted 3 feet. Those of either side are 3½ feet wide and 10 feet 3 inches high; making an actual space in width of 12 feet, which is 1 foot 6 inches more than the whole width of the church aisles. The doors are entered by five steps, which are built of southern pine, and extend the entire length of the vestibule, including a buttress 3 feet wide at either end. This brings us to the interior of the building.

As has been before stated, the entrance was but five steps from the grading on the front end, so that the entrance floor is five feet lower than the pew floor; a space of four feet is left at the entrance on the inside, the entire length of the vestibule, 24 feet. And at that distance from the doors, a flight of eight stairs, 13 feet long, lead up to the entry of the church; which entry is 7½ feet wide, and runs the entire width of the church on the inside. These stairs are very easy of ascent, and, being 13 feet long, amount to 2½ feet more than the width of all the aisles, so that these, together with the outside doors, insure against any jam being produced in the entry of the building, which is one of the evils with which the architect has often to contend.

On either side of the main stairs to the church are those leading to the vestry; these are each 4½ feet wide, making a passage-way of 9 feet; they are built of southern pine, as are also the floors of all the entries, and are oiled over, leaving the natural color of the wood. A large mahogany rail and southern pine balusters commence at the foot of those to the vestry, and are continued up around the well-room over those to the church, and returns at the top railing in the space on the upper entry, which is not occupied by those leading to the entrance floor.

An arch is sprung over each of the three openings at the top of the church stairs; these openings are made by a square pillar coming down at the head of the stairs on either side, so that, beneath these three arches, the whole space is open on the church entry floor the entire width of the vestibule, which gives to the whole a spacious and airy appearance. From this floor, stairs on either end lead to the singing gallery. Beneath this entry, on the vestry floor, is one of the same width, and from it is a door 4 feet wide, leading to the outside of the building; one leading to a room 12 feet square, for wood and coal, beneath the church stairs; also two others leading to the vestry, the dimensions of which are 42 by 49 feet, and 11 feet high in the clear; connected with which are two ante-rooms, each 20 feet 6 inches by 22 feet. Attached to each of these rooms is a closet, 4 feet wide and 11 feet long. The ante-rooms are separated from the vestry by large doors, which move on castors, so that the whole may be thrown into one large room.

The floor of the church contains 82 pews, 2 feet 10 inches wide, and 9 feet 7 inches in length, which provides 19 inches to a person, allowing 6 persons to a pew, making the house capable of seating in all, including the gallery, 550 persons. The side aisles are 3 feet wide; the one in the centre, 4½ feet.

The pulpit is of an original design, and is in strict accordance with the architectural character of the edifice. It is an imitation of rosewood, and the seven circular-headed panels on the front are lined with garnet plush. The sofa connected with the pulpit is of rosewood, and was designed for the place it occupies; the trimmings of the sofa, pulpit, and chairs are also of garnet plush.

There is a choir gallery at the end of the church, over the entrance, connected with which is a room for the choir's rehearsals, 24 by 12 feet, and 12 feet high. There is a dado in each of the side aisles of the main floor, to the height of the window sills, which is returned at the sides of each window, making a pedestal of sufficient width to include the window and the fresco pilasters at its sides. This dado has a capping and base, which, together with the doors of the church, are grained black walnut.

The windows of the whole building, above the basement, are furnished with blinds on the inside, and are painted Paris green. The walls of the principal room are 24 feet high, and these, with the whole interior of the church, are finely painted in distemper fresco, in the following manner: The side walls have a fine fluted Corinthian pilaster on each side of all the windows, which support an entablature 3 feet deep, extending entirely around the church walls; between each of these is a sunken panel, and inside of these is one which is raised; over the windows is a rich moulding ornamented with a console, and ending at the pilasters with an acanthus leaf. On the back end, on either side of the recess, back of the pulpit, is painted a niche standing on a pedestal, and finished like the windows. In the recess back of the pulpit is represented an arched panelled recess or passage, leading to a rotunda, in the centre of which stands a large cross; the ceiling is very finely decorated by large panels, and at the angles are ornaments of Roman foliage, extending some 11 feet either way. In the centre of the ceiling is a cast-iron register, 3 feet in diameter, to admit the foul air to one of Emerson's ventilators, (which effectually ventilates the room;) around this is a beautiful design of foliage, and on two of its sides is seen a harp, supported by the leaves and scrolls. The tint of the ground is a gray lilac. The building was raised in November last, and has been entirely completed since that time. It has cost, including the land and furnishing, not far from $10,500.

T. W. S.

GOTHIC ARCHITECTURE.

Gothic, or what may be termed, with more propriety, English architecture, is that style which immediately succeeded the Norman, and the most prominent feature of which is the pointed arch, slender columns, and a predominancy of vertical lines. We should have been pleased to have given a full description of this kind of architecture; but our limits not permitting, we shall content ourselves with simply giving a synopsis of some of its characteristics; and to those of our patrons who may wish for a more extensive knowledge of this branch of the science, we would refer them to a work known as the Glossary of Architecture, the fifth edition of which was published in London the past year. This work contains a very elaborate description of all that pertains to this branch of the science, and is a production of inestimable value. We have stated that this species of architecture immediately succeeded the Norman — indeed, it is a work of some nicety to draw the dividing line between them; but, before proceeding further, we will remark that the Rev. Mr. Millers, of England, has divided the architecture on which we treat into three distinct classes, and his classification has met the approval of Rickman and Pugin, who are among the principal architectural writers of England. The first style he terms the Early English, the second the Decorated, and the third the Perpendicular. We shall follow him in this respect, and shall describe each style respectively hereafter.

The Early English, then, is the style which is nearest to the Norman, and it may be said to have grown out of it; and here we beg leave to differ from the opinion that has at times found warm advocates, which is, that the form of the arch which characterizes this species of architecture was suggested by the intersection of branches of trees. This idea is, without doubt, the production of a fertile imagination, and, like the famous story of Callimachus and the vase at Corinth, it may be regarded as a play of the fancy and a freak of ideality. One of the principal features of the Norman architecture is the very frequent use of the Roman arch; and, by describing a second semicircle with a point in the circumference of one already drawn as a centre, we produce what is familiarly known as the Gothic arch, and a series of these we term *intersected arches.* This also is of frequent occurrence in the later Norman architecture; and we deem it no departure from the principles of logic to deduce from this fact that the arch used in the English architecture was no invention, but simply a transfer to it from the Norman, and that, even with those with whom it originated, it was the result of accident rather than design. We thus give our reasons for the intrusion we make upon the favorite speculations of those who may differ from us, for we do so with all respect to their love of the ideal, and we would be the last to deprive them of the pleasure they may derive from the idea that those with whom one of the most beautiful of the productions of architecture had its origin were men endowed with great inventive talent, and that, too, which often manifested itself to an astonishing degree. But to proceed: we will again remark, that the first style is the Early English, and is, as its name suggests, the earliest of the three. The intersecting arches to which we have before referred characterized the Norman, as it was about to merge into it, and, in some instances, we find examples of the pointed arch in the Norman, entirely by itself; thus the one has produced the other.

The time when this style may be said to have had its rise was about the year 1200, and continued from this period to 1300, which extended through the reigns of John, Henry III., and Edward I. It is stated that, during the reign of Henry III. alone, no less a number than one hundred and fifty-seven abbeys, priories, and other religious houses were founded in England; and the erection of these was considered as among the most effectual means of obtaining the forgiveness of sins, and, consequently, the favor of Heaven. The principal characteristic of this style is, in the language of Gwilt, as follows: The *arches* are sharply lancet pointed, and lofty, in proportion to

their span. In the upper tiers, two or more are comprehended under one, finished in trefoil or cinquefoil heads, instead of points, the separating columns being slender. *Columns* on which the arches rest are very slender in proportion to their height, and usually consist of a central shaft, surrounded by several smaller ones. The base takes the form of the cluster and the capital is frequently decorated with foliage, very elegantly composed. The *windows* are long, narrow, and lancet-shaped, whence some writers have called this style the Lancet Gothic. They are divided by one plain mullion, or, in upper tiers, by two at most, finished at the top with some simple ornament, as a lozenge, or a trefoil. They have commonly small marble shafts on each side, both internally and externally; two, three, or more, together, at the east or west end, and tier above tier. *Roofs* are high pitched, and the ceilings vaulted, exhibiting the first examples of arches with cross springers only, which, in a short period, diverged into many more, rising from the capitals of the columns, and almost overspreading the whole surface of the vaulting.

The longitudinal horizontal line which reigned along the apex of the vault was decorated with bosses of flowers, figures, and other fancies. *Walls* much reduced in thickness from those of the preceding period; they are, however, externally strengthened with buttresses, which, as it were, lean against them for the purpose of counteracting the thrust exerted by the stone vaults which form the ceilings, and which the walls and piers, by their own gravity, could not resist. The buttresses are, moreover, aided in their office by the pinnacles, adorned with crockets at their angles, and crowned with finial flowers, by which they are surmounted. The *ornaments* now become numerous, but they are simple and elegant. The mouldings are not so much varied as in the Norman style, and are generally, perhaps universally, formed of some combination of leaves and flowers, used not only in the circumference of arches, especially of windows, but the columns or pilasters are completely laid down with them — trefoils, quatrefoils, cinquefoils, roses, mullets, bosses, pateræ, &c., in the spandrils, or above the keystones of the arches, and elsewhere. The ornamental pinnacles on shrines, tombs, &c., are extremely high and acute, sometimes with, and sometimes without, niches under them. In east and west fronts, the niches are

18

filled with statues of the size of life, and larger, and are crowned with trefoil, &c., heads, or extremely acute pediments, formed by the meeting of two straight lines, instead of arcs. All these ornaments are more sparingly introduced into large, entire edifices than in smaller buildings or added parts. The *plans* are, generally, similar to those of the preceding period; but that important feature, the tower, now begins to rise to a great height, and lanterns and lofty spires are frequent accompaniments to the structure. It will naturally occur to the reader, that, in the transition from the Norman to this style, the architects left one extreme for another, though it has been contended that the latter has its germ in the former. However that may be, the period of which we are now speaking was undoubtedly the parent of the succeeding styles, and that by no very forced or unnatural relationship.

The principal examples of the early English style, in the cathedral churches of England, are to be seen at *Oxford*, in the chapter-house; *Lincoln*, in the nave and arches beyond the transept; *York*, in the north and south transept; at *Durham*, in the additional transept; *Wells*, the tower and the whole western front; *Carlisle*, the choir; *Ely*, the presbytery; *Worcester*, the transept and choir; *Salisbury*, the whole cathedral — the only unmixed example; at *Rochester*, the choir and transept. "It is well worthy of observation," says Mr. Dallaway, "that though the ground plans of sacred edifices are, generally speaking, similar and systematic, yet in no single instance which occurs to my memory do we find an exact and unvaried copy of any building which preceded it, in any part of the structure. A striking analogy of resemblance may occur, but that rarely."

The second class or style is the Decorated, and occupied the period between 1300 and 1460. "In the early part of the period," continues Gwilt, "the change, or rather progress, was extremely slow, and marked by little variation; and indeed, until 1400, the style can scarcely be said to have been perfected; but after that time, it rapidly attained all the improvement whereof it was susceptible, and so proceeded till about 1460, after which it assumed an exuberance of ornament, beyond which, as it was impossible to advance, it was in a predicament from which no change could be effected but by its total abandonment. This style exhibits *arches*, less acute and more open, the forms varying."

Columns. — The central and detached shafts are now worked together into one, from experience of the weakness of those of the previous style, exceedingly various in their combinations.

The *windows* are larger, divided by mullions into several lights, spreading and dividing at the top into leaves, flowers, fans, wheels, and fanciful forms of endless variety. These marks are constant, but in the proportionate breadth there is much variation; for, after having expanded in the reigns of Edward I. and II., they grew narrower again in proportion to their height in that of Edward III., and also sharper. The head was then formed of lines just perceptibly curved, sometimes even by two straight lines, sometimes just curved a little above the haunches, and then rectilinear to the apex. The eastern and western windows were very lofty and ample, and splendidly decorated with painted glass. In regard to the *roof* or *ceiling*, the vaulting is more decorated. The principal ribs spread from their imposts, running over the vault like tracery, or, rather, with transoms divided into many angular compartments, and ornamented at the angles with heads, orbs, historical or legendary pictures, &c., elaborately colored and gilded. The *ornaments* are more various and labored, but not so elegant and graceful in character, as in the preceding style. Niches and tabernacles, with statues, are used in great abundance. Tiers of small ornamental arches are frequent. The pinnacles are neither so lofty nor tapering, but are more richly decorated with leaves, crockets, &c. Sculpture is introduced in much profusion, and is frequently painted and gilt; screens, stalls, doors, panelled ceilings, and other ornaments in carved and painted wood.

Some of the principal examples of the ornamented English style in cathedral churches are, at *Exeter*, the nave and choir; *Lichfield*, uniformly; at *Lincoln*, the additions to the central tower; at *Worcester*, the nave; *York*, nave, choir, and western front; at *Canterbury*, transept; at *Gloucester*, transept and cloisters began; *Norwich*, the spire and tower; *Salisbury*, spire and additions; *Bristol*, the nave and choir; *Chichester*, the spire and choir; *Ely*, Our Lady's Chapel, and the central louvre; *Hereford*, the chapter-house and cloisters, now destroyed. In the later part of the period, the choir at *Gloucester*, the nave at *Canterbury*, Bishop Beckington's additions at *Wells*, and from the upper transept to the great east window at *Lincoln*.

FLORID ENGLISH, OR PERPENDICULAR STYLE.

"There is," as Dr. Henry observes, "a certain perfection in art to which human genius may aspire with success, but beyond which it is the apprehension of many that improvement degenerates into false taste and fantastic refinement." "The rude simplicity of Saxon architecture was [ultimately] supplanted by the magnificence of the ornamental Gothic; but magnificence itself is at last exhausted, and it terminated during the present period in a style censurable as too ornamental, departing from the grandeur peculiar to the Gothic, without acquiring proportional elegance; yet its intricate and redundant decorations are well calculated to rivet the eye, and amaze, perhaps bewilder, the mind." The period of this style is from 1460 to the dissolution of the religious houses in 1537, and comprehends, therefore, the reigns of Edward IV. and V., Richard III., Henry VII. and VIII.

Its principal characteristics are *arches*, universally flat, and wide in proportion to their height. The *windows* are much more open than in the last period, flatter at the top, and divided in the upper part by transoms, which are almost constantly crowned with embattled work in miniature. The *ceilings*, or *vaultings*, spread out into such a variety of parts that the whole surface appears covered with a web of delicate sculpture or embroidery thrown over it; and from different intersections of this ribbed work, clusters of pendent ornaments hang down, as Mr. Miller observes, like "stalactites in caverns." The *flying buttresses* are equally ornamented, and the external sufaces of the walls are one mass of delicate sculpture. The *ornaments*, as may be deduced from the above particulars, are lavish and profuse in the highest degree. Fretwork, figures of men and animals, niches and tabernacles, accompanied with canopies, pedestals, and traceries of the most exquisite workmanship, carried this style to the summit of splendor; and all these combined had, perhaps, no small share in producing the extinction it was doomed to undergo.

Roslin and *Holyrood* Chapels, the first whereof was erected by Sir William St. Clair, for richness and variety of ornamental carvings cannot be exceeded. Its plan is without parallel in any other specimen of the fifteenth century. The latter was finished by

James, the second of that name, in 1440, and is a beautiful example, with flying buttresses, which are more ornamented than any even in England. Examples of the Florid Gothic or Perpendicular style are to be seen at the cathedral churches of *Gloucester*, in the Chapel of Our Lady; at *Oxford*, in the roof of the choir; at *Ely*, in Alcock's Chapel; at *Peterboro'*, in Our Lady's Chapel; and at *Hereford*, in the north porch. In conventual churches at *Windsor*, St. George's Chapel at *Cambridge*, King's College Chapel at *Westminster*, King Henry VII.'s Chapel; at *Great Melvern*, in Worcestershire, the tower and choir; at *Christ's Church*, Oxford, the roof of the choir; and at *Evesham Abbey*, in Worcestershire, the campanile and gateway.

Among other principal examples in this style, it may be well to mention that Scotland boasts of many fine specimens of ecclesiastical architecture. The Abbeys of Melrose and Kelso, founded by David I., as well as those in Dryburgh and Jedburgh,—all in Roxburghshire,—prove that the art advanced to as great perfection north of the Tweed as it did in England.

For parochial churches, except in some very few specimens in Somersetshire, and there, perhaps, only in parts, we are unable to refer the reader to a complete specimen, in all its parts, of the perpendicular style. The pulpit and screen at Dartmouth, in Devonshire, are worthy of his notice.

The following synoptical view of the general dimensions of the above cathedrals, we think, may prove occasionally useful to the reader, by enabling him to compare the whole of them and their parts with each other. Dallaway, without the remotest idea of the principles in question, has observed, with his usual sagacity, that there appears in them "a distribution of parts which will hold almost generally, that the width of the nave is that of both the aisles, measured in the place to the extremity of the buttresses externally; and that the breadth and height of the whole building are equal. In the more ancient churches, the aisles are usually of the width of the space between the dividing arches." Some idea of the principle is conveyed in the plates of Milan Cathedral, curiously introduced into the very early translation of Vitruvius by Cæsar Cesarianus, a work of great curiosity, and of which copies are now rarely met with.

A Synoptical View of the leading Dimensions of the English Cathedrals.

Cathedral.	Total internal Length.	Naves and Aisles.			Choirs.			Transepts.	Spires and Towers.	
		Length.	*Breadth.*	*Height.*	*Length.*	*Breadth.*	*Height.*	*Breadth.*		*Height.*
Winchester, .	545	247	86	78	138	—	73	186		
Ely, . . .	517	327	73	70	101	73	70	178	Tower, .	210
Canterbury, .	514	214	70	80	150	74	80	154	Do., . .	235
Old St. Paul's, .	500	335	91	102	165	42	88	248	Spire, .	534
York, . . .	498	264	109	99	131	—	99	222	Tower .	234
Lincoln, . .	498	—	83	83	—	—	—	227	Do., . .	260
Westminster, .	489	130	96	101	152	—	151	189		
Peterboro', . .	480	231	78	78	138	—	78	203	Louvre, .	150
Salisbury, . .	452	246	76	84	140	—	84	210	Spire, .	387
Durham, . .	420	—	—	—	117	33	71	176	Tower, .	214
Gloucester, .	420	174	84	67	140	—	86	144	Do., . .	225
Lichfield, . .	411	213	67	—	110	—	67	—	Spire, 258 W.	183
Norwich, . .	411	230	71	—	165	—	—	191	Do., . .	317
Worcester, .	410	212	78	—	126	—	74	130	Tower, .	196
Chichester, .	401	205	91	61	100	—	—	131	Spire, .	267
Exeter, . .	390	173	74	69	131	—	69	140	Tower, .	130
Wells, . .	371	191	67	67	106	—	67	135	Do., . .	160
Hereford, anct. .	370	144	68	68	105	—	64	140		
Chester, .	348	—	73	73	—	—	—	—	Tower, .	127
Rochester, . .	306	150	65	—	156	—	—	122	Spire, .	156
Carlisle, . .	213	—	71	71	137	71	—	—		
Bath, . .	210	136	72	78	—	—	—	126	Tower, .	162
Bristol, . .	175	100	75	73	100	—	—	128	Do., . .	127
Oxford, . .	154	74	54	41	80	—	$37\frac{1}{2}$	102	Spire, . .	184

To the above we subjoin the correspondent dimensions of the several component parts of some of the cathedral churches enumerated, which we consider useful to the student as well as the general reader.

Total Length.

	Feet.
Chichester cathedral church,	410
Norwich cathedral church,	411
Worcester cathedral church,	410
Durham cathedral church,	420
Gloucester conventual church,	420

	Heights of Naves. Feet.	Style.
Salisbury cathedral church,	84	Pointed arch.
Lincoln cathedral church,	83	Pointed arch.
Canterbury cathedral church,	80	Pure Gothic.
Peterboro' conventual church,	78	Norman.
Winchester cathedral church,	78	Pure Gothic.
Durham cathedral church,	71	Norman.
Ely cathedral church,	70	Norman.
Exeter cathedral church,	69	Pointed arch.
Gloucester conventual church,	67	Norman.
Wells cathedral church,	67	Pointed arch.

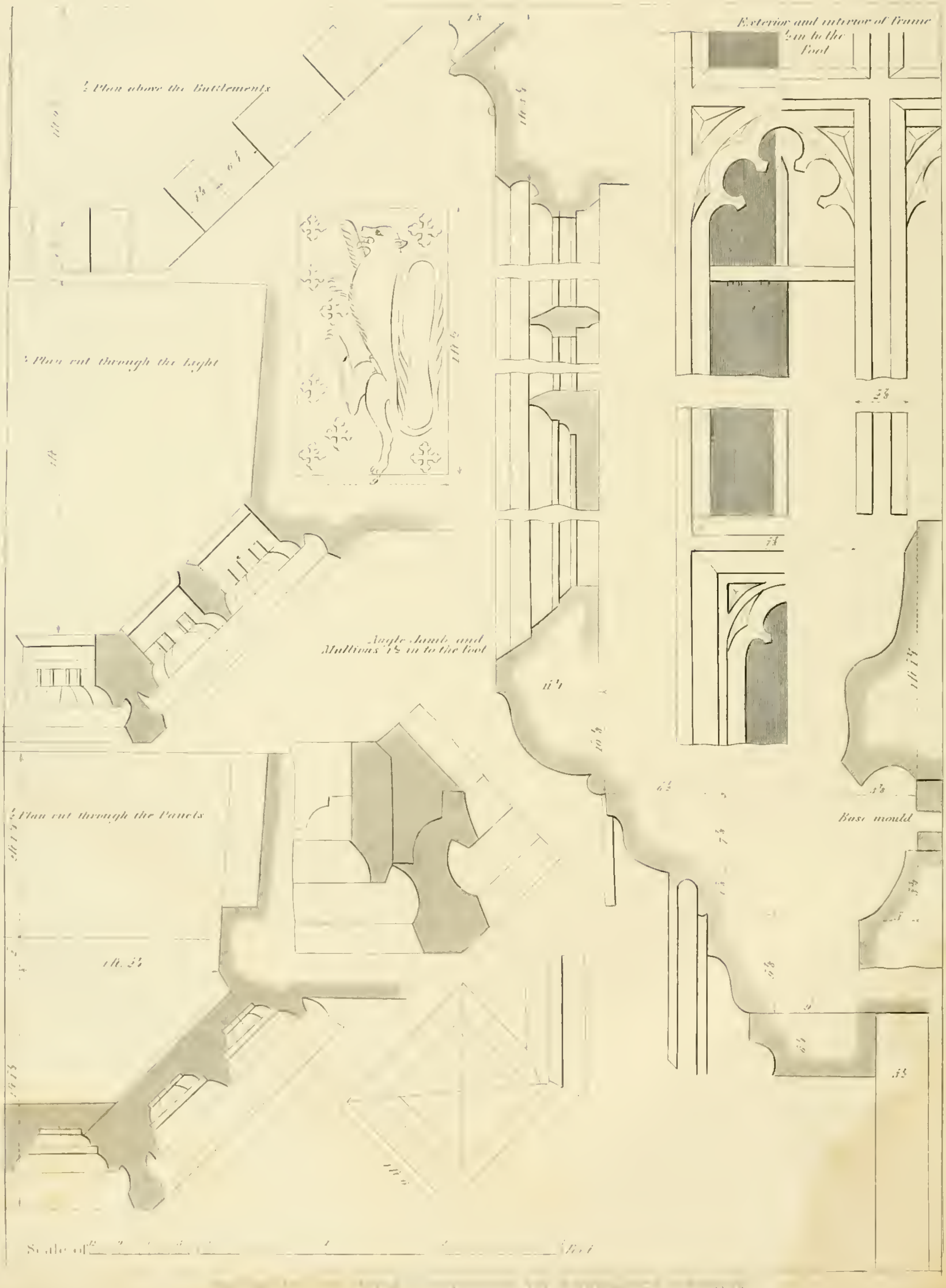
Breadths of Naves and Aisles.

	Feet.		Feet.		Feet.
Norwich,	71	Exeter,	74	Durham,	80
Bristol,	73	Salisbury,	76	Lincoln,	83
Chester,	73	Peterboro',	78	Gloucester,	84
Ely,	73	Worcester,	78	Winchester,	85
Canterbury,	74				

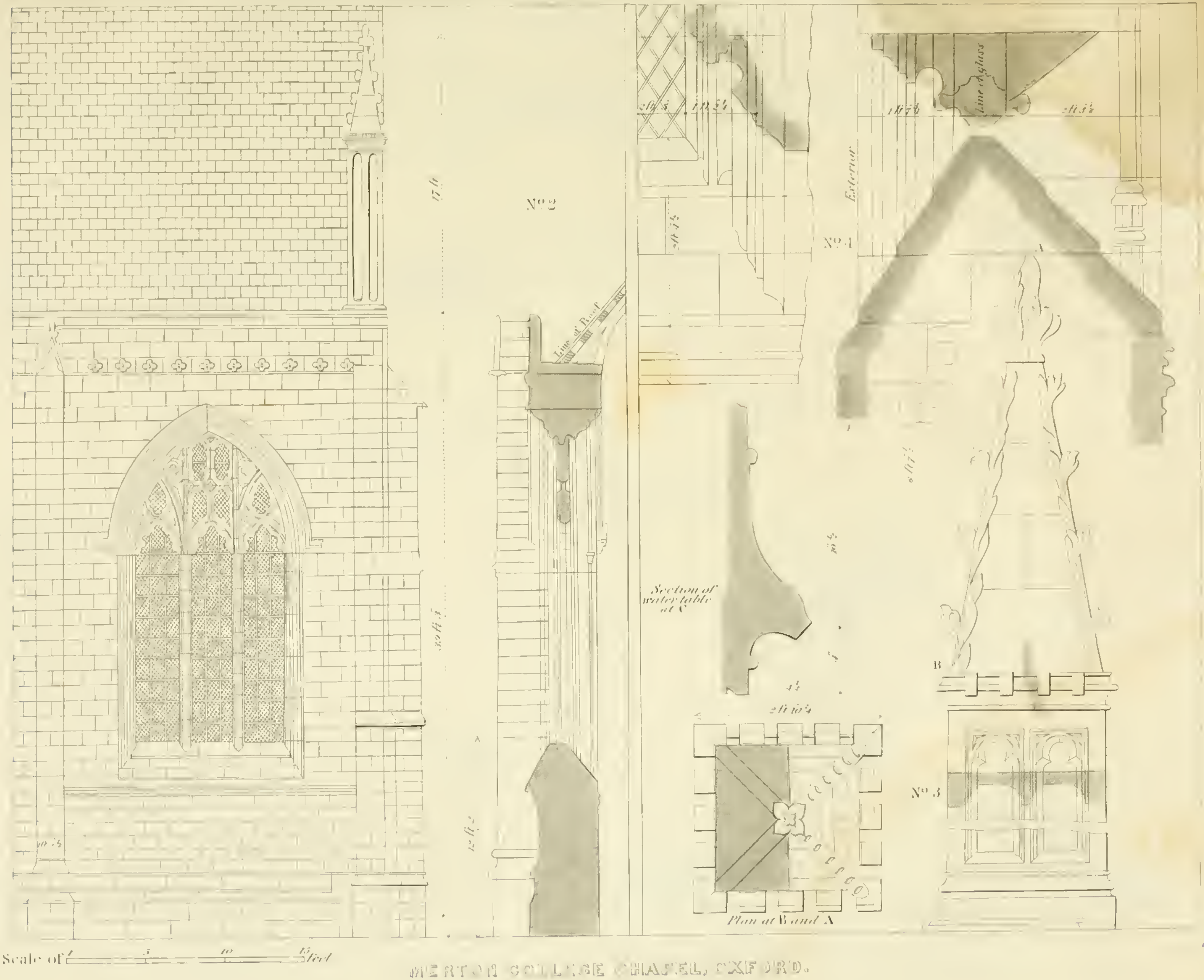
The author just quoted, in reference to the tables here given, says of them, that "the parallel will afford us, at one view, authentic information concerning the proportion of one constituent part to another of every cathedral in England which is worthy the notice of an architect. Such," he continues, "a coincidence of dimensions as that which is found in many of them can scarcely be supposed to be the effect of chance, especially where the buildings are contemporary, and of an exactly correspondent style." It appears that the equality of proportions is confined to each era and style of ecclesiastical architecture in so remarkable a degree as to lead us to conjecture that they might have been designed by the same architect. "The constant rivalry," says Dallaway, "which subsisted between the magnificent prelates, was excited upon the erection of any part of a cathedral of superior beauty, and imitated in those of the same kind which were then undertaken; and the architect who had once displayed great talents was invited to repeat the more perfect performance upon which he had rested his professional fame." We have not considered it necessary to devote a special portion of our work to the conventual architecture of England, because it followed the style of the time. It was of great splendor. The ground plans of their habitable portions were usually, though not always, quadrangular, and in the later ages partook of the improvements in domestic architecture, as in the colleges built by Wykham and Waynflete, and many of the episcopal residences. Glastonbury and Reading presented exceedingly fine examples of it; the former comprised within its walls sixty acres of ground.

We have thus given, although very briefly, an account of the rise and progress of a species of architecture which is in itself a wonder, and which has set up an eternal defiance to him who would speak lightly of the deep conception it develops, or the wonderful fertility of the inventive genius it demonstrates. It was the production of a peculiar age, and, true to its time, it mirrors in every case a transcript of the mind of him who conceived it. The low roof of the Indian Temple of Elephanta, or the Egyptian Philæ or Edfu, were lofty enough for their deities. The Parthenon and the Erectheum of classic Greece were sufficiently spacious and significant of the gods they worshipped; but to the mind of the Christian, whose vision extended beyond the confines of temples that were made with hands, the most gorgeous temple of Grecian story, although composed of the purest marble and of the most classic design, was but mean and grovelling. Their religion was of a loftier nature, and their aspirations could only be satisfied when, with awful sublimity, they saw the spire of Salisbury towering in majestic significance for four hundred feet in the air. In that huge pile, awful yet majestic, they recognized a divinity, the colossal grandeur of which awakened and perpetuated in their bosoms emotions of adoration and praise. Beneath the sky of ancient Rome stands one of the seven wonders of the world; and, beneath that of London, the glory of Roman architecture on the soil of Old England. But in constructing the Cathedral Churches of St. Peter's and St. Paul's, the conception of Raphael, and An-

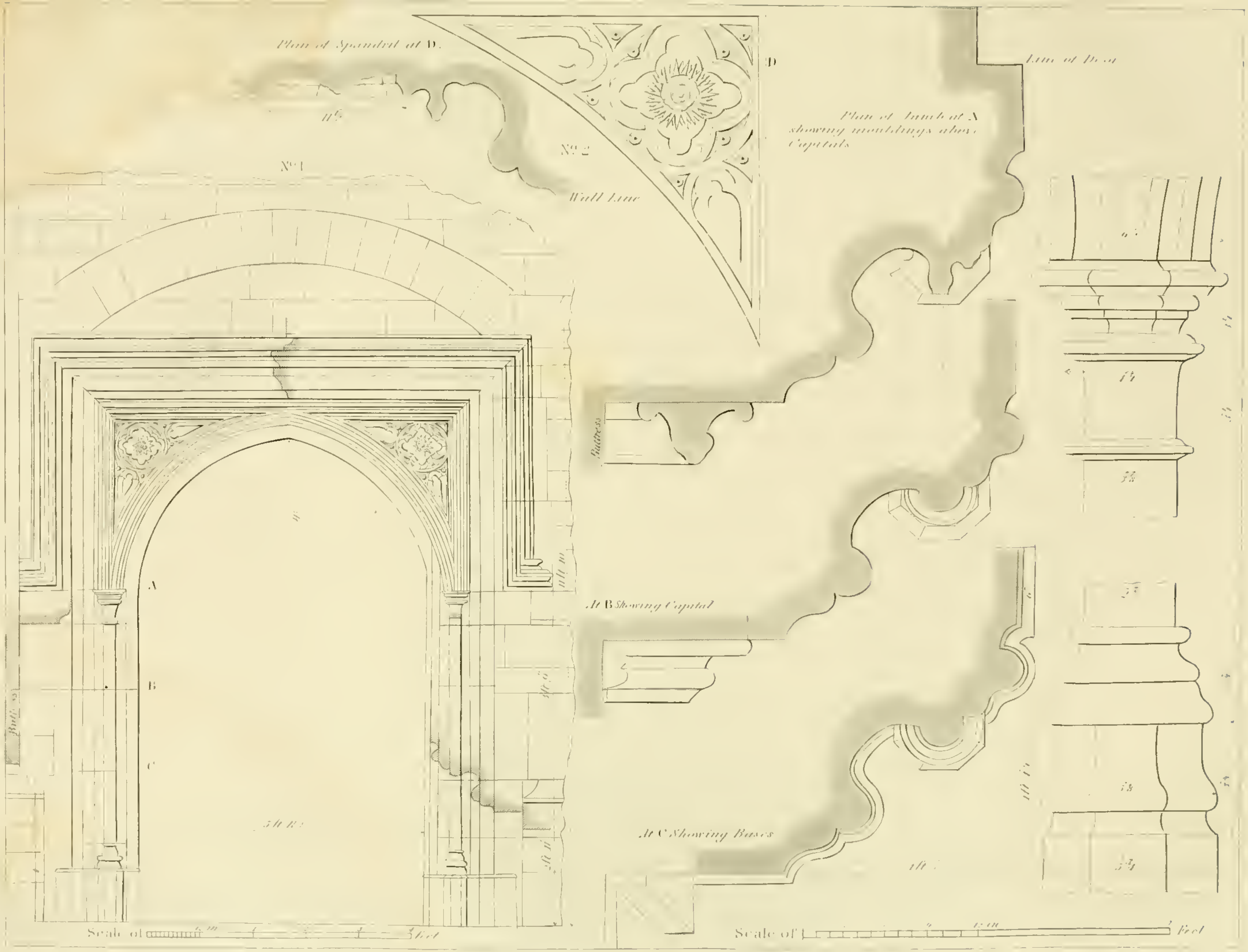
Elevation and Section of the Oriel Window in the entrance gateway


½ Plan above the Battlements
½ Plan cut through the Light
½ Plan cut through the Panels
Angle Jamb and Mullions 1½ in to the Foot
Exterior and interior of Frame ½ in to the Foot
Base mould
Scale of Feet

PL. 100



MERTON COLLEGE CHAPEL, OXFORD.



ELTHAM PALACE, KENT

No. 1 Doorway on the North side of Hall. Nos. 2, 3, 4, Spandril Plans, Capital and Base of Do.

gelo, and Wren were trammelled by the rules and proportions of an order, and a Roman sternness characterizes each pile. In these is seen, it is true, the great victory that science and skill have won over disorder and ignorance, but in Gloucester and Winchester the very essence of art and ideality. The perfect columniations and nicely-arranged entablatures of the former speak to us, it is true, with a boldness that well becomes the Roman; but the flowing tracery and lofty arches of the latter breathe an air of poetry: while the great domes of the one fill the mind with majesty and awe, the towering spires of the others address their solemn eloquence to the soul.

We would not underrate the talent which produced the great realities we place in contrast; we give them the glory which a matured science and a ripe skill have hung around them; but we claim for the others that each conception is distinctly identified with the time which gave it birth, and that they were the outgushings of souls who were striving to gain the mastery over darkness and degradation, and whose loftiest aspirations were the establishment and perpetuity of a reformed religion; that they are the mementoes of a genius and invention which were lent to a people who had been appointed to assist at an important era in a reform which is to ultimately rid the race of their vices and transgressions. It is to be acknowledged that the means made use of by the clergy were often censurable, and at variance with the principles of the religion they would inculcate; but, notwithstanding all this, behind the definite and sharp scientific outlines with which the reason and experience of six centuries have bounded the dominion of religious duty, we see standing out from it all a determination and an accomplishment; an intense desire, amounting in itself to a demand, for a deeper reverence for the principles of religion, as they understood them, and now, after six centuries have elapsed, the crowded aisles of a hundred cathedrals speak out their triumph and success, and the walls which enclose them are but votive monuments of the immensity of their wonderful genius. — Editors.

Plates 98, 99, 100, 101.

On these plates we have given examples of Gothic architecture, with their details. These plates are transcripts of the examples they are designed to represent, and are taken from Pugin's Gothic Architecture, with the figures and scale annexed. They are not inserted as illustrations of either of the styles we have described, neither do we give them as elements of those styles, for did we attempt to illustrate each style in a manner that would do justice to the student, some twelve plates, at least, would be required to give him even a limited knowledge of the arches, doors, windows, and columns belonging to each style; and to continue the illustration by examples of roofs, ceilings, mouldings, &c., &c., all of which would be demanded, twice that number would be required in addition; and as it was not the original design of the work to treat upon this part of the science, we have contented ourselves with giving our patrons a description of the principal elements which compose it, and would refer them, in addition to the works we have named, to Rickman's Gothic Architecture, and also to the publications of Britton and Pugin.

The four plates alluded to contain so great a variety of useful and practical information for the country artisan, or to those who do not have access to the works to which we refer them, (and for those our whole work is principally designed,) that we have been induced to place them in our edition. — Editors.

BUILDING.

Aldrich tells us that, in choosing a situation for building, its vicinity to public edifices should be principally attended to; that is, we should build as near as convenient to the place where the business of the owner chiefly calls him. "Every one would wish to be near a church," (or, perhaps, should wish to be so,) "but especially a priest; the lawyer near the hall of justice; the merchant near the exchange; the trader in the principal street; and every other citizen, in the same manner, would choose his dwelling according to his occupation — not far from the river, if any flow near the city; at a distance from a tallow chandler, a brewer, a soap boiler, or any other business attended with an unsavory smell; far from the noise of the anvil, the hammer, and the saw; and, above all, (as Cato says,) at a distance from bad neighbors. In short, that spot is most eligible in which you can construct a regular house; that is, one with right angles — where room, leisure, and cleanliness may be obtained, and you may procure to your house the advantages of a rural situation. If all the above conveniences cannot be met with, (and it is very seldom, if desired, that they can be,) it is prudent to aim at such as may be desirable and are attainable.

Under this general term, which implies the construction of an edifice, according to the rules laid down by the different artificers employed, we purpose to treat of the respective business of the mason, bricklayer, plasterer, slater, plumber, painter, and glazier; previous to which it will be necessary to consider the sinking of the foundation, the due mixture of the ingredients which compose the mortar, and the art of making bricks, upon the whole of which materially depends the stability of an edifice.

As firmness of foundation is indispensable, wherever it is intended to erect a building, the earth must be pierced by an iron bar, or stuck with a rammer, and, if found to shake, must be bored with a well-sinker's implement, in order to ascertain whether the shake be local or general. If the soil is in general good, the loose and soft parts, if not very deep, must be excavated until the laborers arrive at a solid bed capable of sustaining the pier or piers to be built. If not very loose, it may be made good by ramming into it very large stones, packed close together, and of a breadth proportionate to the intended weight of the building; but where very bad, it must be piled and planked.

In places where the soil is loose to any great depth, and over which it is intended to place apertures, such as doors, windows, &c., while the parts on which the piers are to stand are firm, the best plan is to turn an inverted arch under each intended aperture, as then the piers, in sinking, will carry with them the inverted arch, and, by compressing the ground, compel it to act against the under sides of the arch, which, if closely jointed, so far from yielding, will, with the abutting piers, operate as one solid body; but, on the contrary, if this expedient of the inverted arch is not adopted, the part of the wall under the aperture, being of less height, and, consequently, of less weight than the piers, will give way to the resistance of the soil acting on its base, and not only injure the brick work between the apertures, but fracture the window heads and sills.

In constructing so essential a part as the arch, great attention must be paid to its curvature, and we strongly recommend the parabolic curve to be adopted, as the most effectual for the purpose; but if, in consequence of its depth, this cannot conveniently be introduced, the arch should never be made less than a semicircle. The bed of the piers should be as uniform as possible; for though the bottom of the trench be very firm, it will, in some degree, yield to the great weight that is upon it, and if the soil be softer in one part than in another, that part which is the softest will, of course, yield more to the pressure, and cause a fracture.

If the solid parts of the trench happen to be under the intended apertures, and the softer parts where piers are wanted, the reverse of the above practice must be resorted to; that is, the piers must be built on the firm parts, and have an arch that is not inverted between them. In performing this, attention must be paid to ascertain whether the pier will cover the arch; for if the middle of the pier rest over the middle of the summit of the arch, the narrower the pier is the greater should be the curvature of the arch at its apex. When suspended arches are used, the intrados ought to be kept clear of the ground, that the arch may have its due effect.

When the ground is in such a state as to require the foundation merely to be rammed, the stones are hammer dressed, so as to be of as little taper as possible, then laid of a breadth proportioned to the weight

that is to be rested upon them, and afterwards well rammed together. In general, the lower bed of stones may be allowed to project about a foot from the face of the wall on each side, and on this bed another course may be laid, to bring the bed of stones on a level with the top of the trench. The breadth of this upper bed of stones should be four inches less than the lower one; that is, projecting about eight inches on either side of the wall. In all kinds of walling, each joint of every course must fall as nearly as possible in the centre, between two joints of the course immediately below it; for, in all the various methods of laying stones or bricks, the principal aim is to procure the greatest lap on each other.

MORTAR.

In making mortar, particular attention must be paid to the quality of the sand, and if it contain any proportion of clay or mud, or is brought from the sea-shore, and contains saline particles, it must be washed in a stream of clear water till it be divested of its impurities. The necessity of the first has been clearly proved by Mr. Smeaton, who, in the course of a long and meritorious attention to his profession as an engineer, has found that when mortar, though otherwise of the best quality, is mixed with a small proportion of unburnt clay, it never acquires that hardness which, without it, it would have attained; and, with respect to the second, it is evident that, so long as the sand contains any saline particles, it cannot become hard and dry. The sharper and coarser the sand is, the better for the mortar, and the less the quantity of lime to be used; and sand being the cheapest of the ingredients which compose the mortar, it is more profitable to the maker. The exact proportions of lime and sand are still undetermined; but in general, no more lime is required than is just sufficient to surround the particles of the sand, or sufficient to preserve the necessary degree of plasticity.

Mortar, in which sand forms the greater portion, requires less water in its preparation, and, consequently, is sooner set. It is also harder and less liable to shrink in drying, because the lime, while drying, has a greater tendency to shrink than sand, which retains its original magnitude. The general proportions given by the London builders is $1\frac{1}{2}$ cwt., or 37 bushels of lime, to $2\frac{1}{2}$ loads of sand; but, if proper measures be taken to procure the best burnt lime and the best sand, and in tempering the materials, a greater portion of sand may be used. There is scarcely any mortar that has the lime well calcined, and the composition well beaten, but that will be found to require two parts of sand to one part of unslaked lime; and it is worthy of observation, that the more the mortar is beaten, the less proportion of lime suffices.

Many experiments have been made, with a view to obtain the most useful proportion of the ingredients, and, among the rest, Dr. Higgins has given the following: "Lime, newly slaked, one part; fine sand, three parts; and coarse sand, four parts."

He also found that one fourth of the lime of bone ashes greatly improved the mortar, by giving it tenacity and rendering it less liable to crack in the drying.

It is best to slake the lime in small quantities as required for use, about a bushel at a time, in order to secure to the mortar such of its qualities as would evaporate were it allowed to remain slaked for a length of time. But if the mortar be slaked for any considerable time previous to being used, it should be kept covered up, and, when wanted, should be rebeaten. If care be taken to secure it from the action of the atmosphere, it may thus remain covered up for a considerable period, without its strength being in the least affected; and, indeed, some advantages are gained, for it sets sooner, is less liable to crack in the drying, and is harder when dry.

Grout, which is a cement containing a larger proportion of water than the common mortar, is used to run into the narrow interstices and irregular courses of rubble-stone walls; and as it is required to concrete in the course of a day, it is composed of mortar that has been a long time made and thoroughly beaten.

Mortar, composed of pure lime, sand and water, may be employed in the linings of reservoirs and aqueducts, provided a sufficient time is allowed for it to dry before the water is let in; but if a sufficient time is not allowed, and the water is admitted while the mortar is wet, it will soon fall to pieces. There are, however, certain ingredients which may be put into the common mortar to make it set immediately under the water; or, if the quicklime composing the

mortar contains in itself a certain portion of burnt clay, it will possess this property. For further information on this head, the reader is referred to the sub-head — *Plastering.*

MASONRY.

Masonry is the art of cutting stones, and building them into a mass, so as to form the regular surfaces which are required in the construction of an edifice.

The chief business of the mason is to prepare the stones, make the mortar, raise the wall with necessary breaks, projections, arches, apertures, &c., as indicated by the design.

A wall built of unhewn stone, whether it be built with mortar or otherwise, is called a *rubble wall.* Rubble work is of two kinds, coursed and uncoursed. In coursed rubble, the stones are gauged and dressed by the hammer, and thrown into different heaps, each heap containing stones of equal thickness; and the masonry, which may be of different thicknesses, is laid in horizontal courses. In uncoursed rubble, the stones are placed promiscuously in the wall, without any attention being paid to arrange them in courses; and the only preparation the stones undergo is that of knocking off the sharp angles with the thick end of a tool called a *scabling* hammer. Walls are often built with an ashlar facing of fine stone, averaging about four or five inches in thickness, and backed with rubble work or brick.

Walls backed with brick or uncoursed rubble are liable to become convex on the outside, from the great number of joints, and the difficulty of placing the mortar, which shrinks in proportion to the quantity, in equal portions, in each joint; consequently, walls of this description are much inferior to those where the facing and backing are built of the same material, and with equal care, even though both of the sides be uncoursed. When the outside of a wall is faced with ashlar, and the inside is coursed rubble, the courses of the backing should be as high as possible, and set within beds of mortar. Coursed rubble and brick backings are favorable for the insertion of bond timber; but in good masonry, wooden bonds should never be in continued lengths, as, in case of either fire or rot, the wood will perish, and the masonry will, by being reduced, be liable to bend at the place where the bond was inserted.

When timber is to be inserted into walls for the purposes of fastening buttons for plastering or skirting, &c., the pieces of timber ought to be so disposed that the ends of the pieces be in a line with the wall.

In a wall faced with ashlar, the stones are generally about 2 feet or 2½ feet in length, 12 inches in height, and 8 inches in thickness. It is a very good plan to incline the back of each stone, to make all the backs thus inclined run in the same direction, which gives a small degree of lap in the setting of the next course; whereas, if the backs are parallel to the front, there can be no lap where the stones run of an equal depth in the thickness of the wall. It is also advantageous to the stability of the wall to select the stones, so that a thicker and a thinner one may succeed each other alternately. In each course of ashlar facing, either with rubble masonry or brick backing, thorough stones should occasionally be introduced, and their number be in proportion to the length of the course. In every succeeding course, the thorough stones should be placed in the middle of every two thorough stones in the course below; and this disposition of bonds should be punctually attended to in all cases where the courses are of any great length. Some masons, in order to prove that they have introduced sufficient bonds into their work, choose thorough stones of a greater length than the thickness of the wall, and afterwards cut off the ends; but this is far from an eligible plan, as the wall is not only subject to be shaken, but the stone is itself apt to split. In every pier, between windows and other apertures, every alternate jamb stone ought to go through the wall with its bed perfectly level. When the jamb stones are of one entire height, as is frequently the case when architraves are wrought upon them, upon the lintel crowning them, and upon the stones at the ends of the courses of the pier which are adjacent to the architrave jamb, every alternate stone ought to be a thorough stone: and if the piers between the apertures be very narrow, no other bond stone is required; but where the piers are wide, the number of bond stones are proportioned to the space. Bond stones must be particularly attended to in all long courses below and above windows.

Iron clamps are now used in all cases where it is practicable, instead of thorough stones. The shrinking of the mortar in the backing is very apt to start

the thorough stone from its true position, which either fractures it, or causes the wall to bulge, and open the seams on the outside. This inconvenience is obviated by the use of clamps.

All vertical joints, after receding about an inch with a close joint, should widen gradually to the back, thereby forming hollow spaces of a wedge-like figure for the reception of mortar, rubble, &c. The adjoining stones should have their beds and vertical joints filled from the face about three quarters of an inch inwards, with oil putty, and the rest of the beds must be filled with well-tempered mortar. Putty cement will stand longer than most stones, and will even remain permanent when the stone itself is mutilated. All walls cemented with oil putty, at first look unsightly; but this disagreeable effect ceases in a year or less, when, if care has been taken to make the color of the putty suitable to that of the stone, the joints will hardly be perceptible.

In selecting ashlar, the mason should take care that each stone invariably lays on its natural bed, as, from carelessness in this particular, the stones frequently flush at the joints, and sooner admit the corrosive power of the atmosphere to take effect.

It ought also to be observed, that, in building walls or insulated pillars of small horizontal dimensions, every stone should have its bed perfectly level, and be without any concavity in the middle; because, if the beds are concave, the joints will most probably flush when the pillars begin to sustain the weight of the building. Care should also be taken that every course of masonry in such piers be of one stone.

Having thus given to the practical mason an outline of the subject of walling, we will proceed to the consideration of the more difficult branches of the art — that of constructing arches and vaults.

DEFINITIONS.

An *arch*, in masonry, is that part of a building which is suspended over a given plane, supported only at its extremities, and concave towards the plane.

The upper surface of an arch is called the *extrados;* and the under surface, or that which is opposite the plane, the *intrados.*

The supports of an arch are called the *spring walls.*

The *springing lines* are those common to the supports and the intrados, or the line which forms the intersection of the arch with the surface of the wall which supports it.

The *chord* or *span* is a line extending from one springing line to the opposite one.

Section of the hollow of the arch is a vertical plane, supposed to be contained by the span and the intrados.

The *height* or *rise* of the arch is a line drawn at right angles from the middle of the chord, or spanning line, to the intrados.

The *crown* of the arch is that part which the extremity of the perpendicular touches.

The *haunches* or *flanks* of the arch are those parts of the curve between the crown and the springing line.

When the base of the section, or spanning line, is parallel to the horizon, the section will consist of two equal and similar parts, so that, when one is applied to the other, they will be found to coincide.

Arches are variously named, according to the figure of the section of a solid that would fill the void, as *circular*, *elliptical*, *cycloidal*, *catenarian*, *parabolical*, &c. There are also *pointed*, *composite*, and *lancet* or *Gothic* arches.

A *rampant arch* is when the springing lines are of two unequal heights.

When the intrados and extrados of an arch are parallel, it is said to be *extradossed.*

There are, however, other terms much used by masons: for example, the semicircular are called *perfect arches;* and those less than a semicircle, *imperfect*, *surbused*, or *diminished* arches.

Arches are called *stilted* when they are higher than a semicircle.

A *vault* is an arch used in the interior of a building, overtopping an area of a given boundary, as a passage, or an apartment, and supported by one or more walls, or pillars, placed without the boundary of that area.

Hence an arch in a wall is seldom or never called a vault; and every vault may be called an arch, but every arch cannot be termed a vault.

A *groin vault* is a complex vault, formed by the intersection of two solids, whose surfaces coincide with the intrados of the arches, and are not confined to the same heights. An arch is said to stand upon splayed jambs when the springing lines are not at right angles to the face of the wall.

In the art of constructing arches and vaults, it is necessary to build them in a mould, until the whole is closed; the mould used for this purpose is called a *centre.*

The intrados of a simple vault is generally formed of a portion of a cylinder, cylindroid, sphere, or spheroid; that is, never greater than the half of the solid; and the springing lines which terminate the walls, or when the vault begins to rise, are generally straight lines, parallel to the axis of the cylinder or cylindroid.

A circular wall is generally terminated with a spherical vault, which is either hemispherical, or a portion of a sphere less than a hemisphere.

Every vault which has a horizontal, straight axis is called a *straight vault;* and, in addition to what we have already said, the concavities which two solids form at an angle receive likewise the name of *arch.*

An arch, when a cylinder pierces another of a greater diameter, is called *cylindro-cylindric.* The term *cylindro* is applied to the cylinder of the greatest diameter, and the term *cylindric* to the less.

If a cylinder intersect a sphere of greater diameter than the cylinder, the arch is called a *sphero-cylindric arch;* but, on the other hand, if a sphere pierce a cylinder of greater diameter than the sphere, the arch is called a *cylindro-spheric* arch.

If a cylinder pierce a cone, so as to make a complete perforation through the cone, two complete arches will be formed, called *cono-cylindric arches;* but, on the contrary, if a cone pierce a cylinder so that the concavity made by the cone is a conic surface, the arch is called a *cylindro-conic arch.*

If, in a straight wall, there be a cylindric aperture continuing quite through it, two arches will be formed, called *plano-cylindric arches.*

Every description of arch is, in a similar manner to the above, denoted by the two preceding words — the former ending in *o*, signifying the principal vault, or surface cut through; and the latter in *ic*, signifying the description of the aperture which pierces or intersects the wall or vault.

When groins are introduced merely for use, they may be built either of brick or stone; but, when introduced by way of proportion or decoration, their beauty will depend on the generating figures of the sides, the regularity of the surface, and the acuteness of the angles, which should not be obtruded. In the best buildings, when durability and elegance are equally required, they may be constructed of wrought stone; and, when elegance is wanted, at a trifling expense, of plaster, supported by timber ribs.

In stonecutting, a narrow surface formed by a point or chisel on the surface of a stone, so as to coincide with a straight edge, is called a *draught.*

FORMATION OF STONE ARCHES.

The formation of stone arches has always been considered a most useful and important acquisition to the operative mason; in order, therefore, to remove any difficulties which might arise in the construction of arches of different descriptions, both in straight and circular walls, we shall here introduce a few examples, which, it is hoped, with careful examination, will greatly facilitate a knowledge of some of the most abstruse parts of the art.

Plate 102.

To find the moulds necessary for the construction of a semicircular arch, cutting a straight wall obliquely.

Fig. 1, No. 1. Let A B C D E F G H be the plan of the arch; I K L M the outer line; and N O P Q the inner line on the elevation.

a b c d e, on the elevation, shows the bevel of each joint or bed from the face of the wall; and *a b c d e*, below, gives the mould for the same, where $x\ y$ on the elevation corresponds with $x\ y$ at *a*.

The arch mould, No. 2, is applied on the face of the stone, and, on being applied to the parts of the plan, gives, of course, the bevel of each concave side of the stone with the face — that is, K to O, on the elevation.

To find the mould for constructing a semicircular arch in a circular wall.

Fig. 2, No. 1, is the elevation of the arch, and No. 2 the plan of the bottom bed from *q* to *r*.

a to *b* is what the arch gains on the circle from the bottom bed *k o* to *l;* and *c* to *d* is the projection of the intrados to *p*, on the point *l*, *p*.

Nos. 2, 3, and 4 are plans of the three arch stones, 1, 2, 3, in the elevation; and Nos. 5 and 6 are moulds to be applied to the beds of stones 1 and 2, in which *s c* equals *s c* in No. 2, and *t w* equals *t w* in No. 3.

In No. 1, *k l p o* is the arch or face mould.

When the reader is thoroughly proficient in the construction of arches under given data, as the circumstances of the case may point out, he may proceed to investigate the principles of spherical domes and groins.

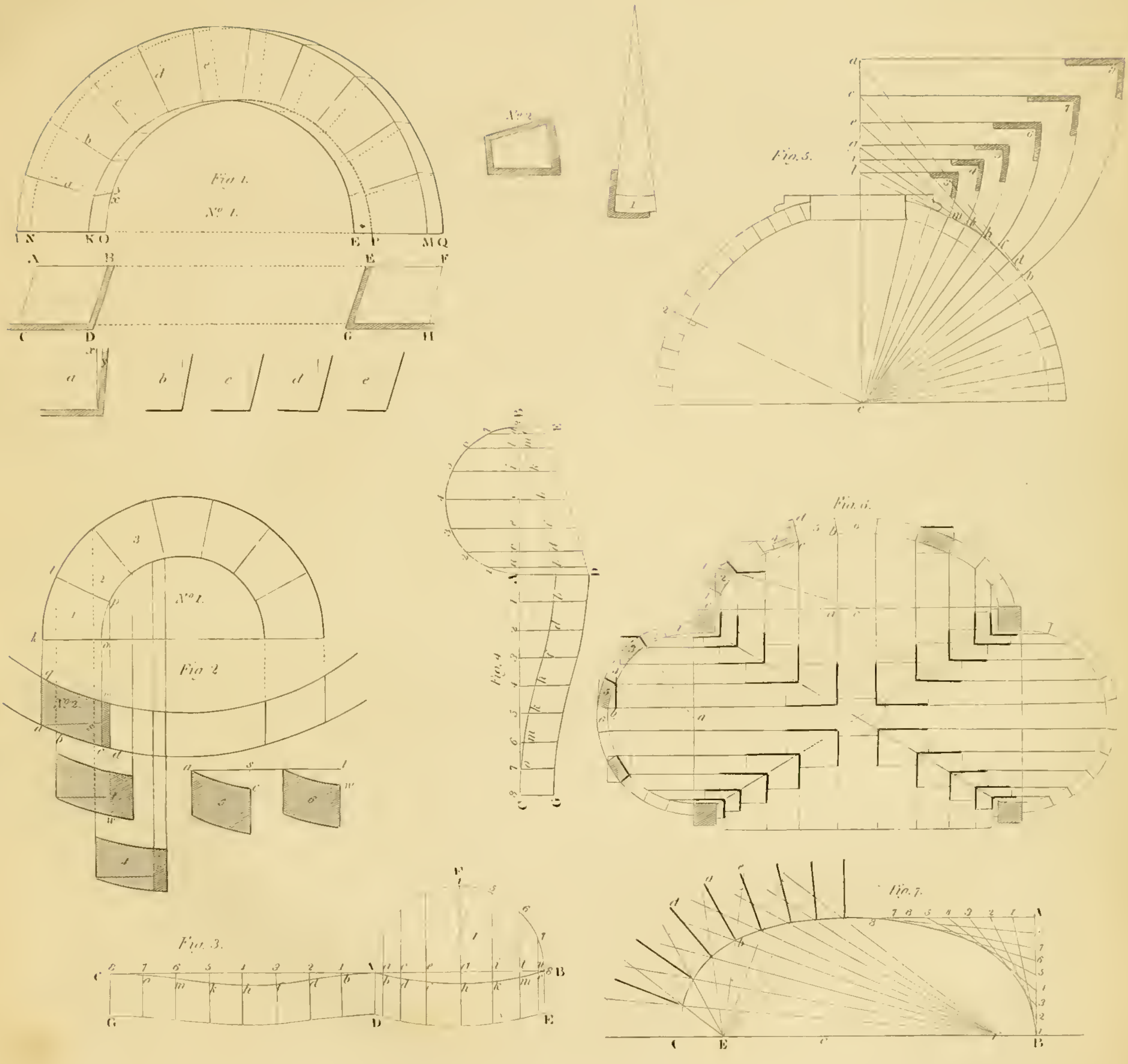


Fig. 1.
No. 1.
No. 2
Fig. 2
Fig. 3.
Fig. 4
Fig. 5.
Fig. 6.
Fig. 7.

Figs. 3 and 4 show the principles of developing the soffits of the arches in the two preceding examples. In each the letters of reference are alike, and the operation is precisely the same.

Let A B D E be the plan of the opening in the wall, and A F B the elevation of the arch; produce the chord A B to C, divide the semicircle A F B into any number of parts, the more the better, and with the compasses set to any one of these divisions, run it as many times along A C as the semicircle is divided into; then draw lines, perpendicular to B C, through every division in the semicircle and the line C A, and set the distance 1 *b*, 2 *d*, 3 *f*, &c., respectively equal to *a b c d e f*, &c., and then, by tracing a curve through these points and finding the points in the line G D, in the same manner, the soffit of the arch is complete.

Fig. 5 shows the method of constructing spherical domes.

No. 1 mould is applied on the spherical surface to the vertical joints, and No. 2 mould on the same surface to the other joints, and, in both cases, the mould tends to the centre of the dome.

3, 4, 5, 6, 7, and 8 are moulds which apply on the convex surface to the horizontal joint, the lines *a b*, *c d*, *e f*, &c., being at right angles to the different radii, *b c*, *d c*, *f c*, &c., and produced until they intersect the perpendicular *a c;* the different intersections are the centres which give the circular leg of the mould, and the straight part gives the horizontal joint.

Fig. 6 exhibits the plan of a groined vault.

Lay down the arch, either at the full or half size, on a floor or piece of floorcloth, then divide and draw on the plan the number of joints in the semicircular arch, and from the intersections with the diagonals draw the transverse joints on the plan, and produce them till they touch the intrados of the elliptical arch, the curve of which may be found by setting the corresponding distances from the line of the base to the curve; thus *a b* equal to *a b*. This being accomplished, draw the joints of the elliptical arch in the manner of which we give *c d* as a specimen. To draw the joint *c d*, draw chord *c c* and bisect it, draw a line from the centre *c* through the bisecting point, and produce it till it touches the perpendicular *e f;* and *c d*, being at right angles to *c f*, will be the joint required. In the same manner the others are found.

By examination, it will be seen that a rectangle circumscribing the mould 3, 3, gives the size of the stone in its square state, and that, if each stone in both arches be thus enclosed, the dimensions for each will be found, as also the position in which the moulds must be placed. The dark lines give the different bevels, which must be carefully prepared and applied to the stones in the manner represented in the figure.

To draw the joints of the stones for an elliptical arch in a wall, &c.

Fig. 7. The curve is here described by the intersection of lines, which certainly gives the most easy and pleasing curve, as segments of circles apply only under certain data, or in the proportion which the axis major has to the axis minor, while the intersection of lines apply to any description of ellipses. Find the foci F. In an ellipsis, the distance of either focus from one extremity of the axis minor is equal to the semi-axis major; that is, D F is equal to *c* C. Then, to find any joint, *a b*, draw lines from both foci through the point *b*, as F *e*, *f d*, and bisect the angle *d b e* by the line *a b*, which is the joint required.

BRICKLAYING.

In building upon an inclined plane, or rising ground, the foundation must be made to rise in a series of level steps, according to the general rise of the ground, to insure a firm bed for the courses, and prevent them from sliding; for if this mode were not adopted, the moisture in the foundations, in wet weather, will induce the inclined parts to descend, to the manifest danger of fracturing the walls and destroying the building.

In walling, in dry weather, when the work is required to be firm, the best mortar must be used, and the bricks must be wetted or dipped in water as they are laid, to cause them to adhere to the mortar, which they would not do if laid dry; for the dry, sandy nature of the brick absorbs the moisture of the mortar, and prevents adhesion.

In carrying up the wall, not more than four or five feet of any part should be built at a time; for, as all walls shrink immediately after building, the part which is first carried up will settle before the adjacent part is carried up to it, and, consequently, the

shrinking of the latter will cause the two parts to separate; therefore, no part of a wall should be carried higher than one scaffold, without having its contingent parts added to it. In carrying up any particular part, the ends should be regularly sloped off, to receive the bond of the adjoining parts on the right and left.

There are two kinds of bond in brick work, which differ materially from each other. Bricks laid lengthwise in the direction of the wall are called *stretchers*, and those laid in an opposite way, crossing the direction of the wall, are called *headers*. The old English bond is a continuation of one kind throughout in the same course or horizontal layer, and consists of alternate layers of headers and stretchers — the headers serving to bind the wall together in a longitudinal direction, or lengthwise, the stretchers to prevent the wall splitting crosswise, or in a transverse direction. Of these two evils, the former is by much the worst kind, and is, therefore, the most dreaded by the bricklayer. The brick work of the Romans was of this kind of bond.

The other description of bond, called *Flemish bond*, consists in placing a header and a stretcher alternately in the same course. The latter is deemed the neatest and most elegant; but, in the execution, is attended with great inconvenience, and, in most cases, does not unite the parts of a wall with the same degree of firmness as the English bond. In general, it may be observed, that whatever advantages are gained by the English bond in tying a wall together in its thickness, are lost in the longitudinal bond, and *vice versa*. To remove this inconvenience in thick walls, some builders place the bricks in a cone at an angle of forty-five degrees, parallel to each other, throughout the length of every course, but reversed in the alternate courses; so that the bricks cross each other at right angles. But even here, though the bricks in the cone have sufficient bond, the sides are very imperfectly tied, on account of the triangular interstices formed by the oblique direction of the internal bricks against the flat edges of those in the outside.

Concerning the English bond, it may be observed, that, as the longitudinal extent of a brick is nine inches and its breadth four and a half, to prevent two vertical joints from running over each other at the end of the stretcher from the corner, it is usual, after placing the return corner stretcher, which occupies half the length of this stretcher, and becomes a header in the face, as the stretcher is below, to place a quarter brick on the side, so that the two together extend six inches and three quarters, being a lap of two inches and a half for the next header. The bat introduced is called a *closer*. A similar effect may be obtained by introducing a three-quarter bat at the corner of the stretching course, so that the corner header being laid over it, a lap of two inches and a quarter will be left at the end of the stretchers below, for the next header, which, being laid on the joint below the stretchers, will coincide with its middle.

In the winter, it is very essential to keep the unfinished wall from the alternate effects of rain and frost; for, if it is exposed, the rain will penetrate into the bricks and mortar, and, by being converted into ice, expand, and burst or crumble the materials in which it is contained.

The decay of buildings, so commonly attributed to the effect of time, is, in fact, attributable to this source; but as finished edifices have only a vertical surface, the action and counteraction of the rain and frost extend not so rapidly as in an unfinished wall, where the horizontal surface permits the rain and frost to have easy access into the body of the work. Great care, therefore, must be taken, as soon as the frost or stormy weather sets in, to cover the unfinished walls either with straw, which is the most common, or weather boarding.

When weather boarding is employed, it is advisable to have a good layer of straw between the work and the boarding, and to place the boarding in the form of stone coping, to throw the water off equally on both sides.

A number of very pleasing cornices and other ornaments may be formed in brickwork, by the mere disposition of the bricks, without cutting; and if cut, a simple chamfer will be sufficient. A great defect, however, is very often observable in these ornaments, particularly in the bulging of arches over windows, which arises from mere carelessness in rubbing the bricks too much on the inside; whereas, if due care were taken to rub them exact to the gauge, their geometrical bearings being united, they would all tend to one centre, and produce a well-proportioned and pleasing effect.

PLASTERING.

The plasterer is a workman to whom the decorative part of architecture owes a considerable portion of its effect, and whose art is requisite in every kind of building.

The tools of the plasterer consist of a *spade* or *shovel* of the usual description; a *rake*, with two or three prongs bent downwards from the line of the handle, for mixing the hair and mortar together; *trowels* of various kinds and sizes; *stopping and picking-out tools;* rules called *straight edges;* and wood *models.*

The trowels used by plasterers are more neatly made than tools of the same name used by other artificers. The *laying and smoothing tool* consists of a flat piece of hardened iron, about ten inches in length, and two inches and a half wide, very thin, and ground to a semicircular shape at one end, but left square at the other; and at the back of the plate, near the square end, is riveted a small iron rod with two legs, one of which is fixed to the plate, and the other to a round, wooden handle. With this tool all the first coats of plaster are laid on, as is also the last, or, as it is technically termed, the *setting.* The other kinds of trowels are made of three or four sizes, for gauging the fine stuff and plaster used in forming cornices, mouldings, &c. The longest size of these is about seven inches on the plate, which is of polished steel, about two inches and three quarters broad at the heel, diverging gradually from a point. To the heel or broad end a handle is adapted.

The *stopping and picking-out tools* are made of polished steel, of different sizes, though most generally about seven or eight inches in length, and half an inch in breadth, flattened at both ends, and ground somewhat round. These tools are used in modelling and finishing mitres and returns to cornices; as, likewise, in filling up, and perfecting the ornaments at the joinings.

The *straight edges* are for keeping the work in an even or perpendicular line; and the *models* or *moulds* are for running plain mouldings, cornices, &c.: of these latter, the plasterers require a greater number, as very little of his finishing can be done without them.

Experienced workmen keep their tools very clean, and have them daily polished.

Plasterers have technical divisions of their work, by which its quality is designated and value ascertained; as, lathing; laying; pricking up; lathing, laying, and set; lathing, floating, and set; screed, set, or putty; rendering and set; or rendering, floated, and set; trowelled stucco, &c.; each of which, hereafter, we shall very minutely explain.

In all the operations of plastering, lime extensively abounds; we shall, therefore, first offer some observations on the properties of this important article.

All who have written on the subject of lime, as a cement, have endeavored to ascertain what is the due proportion of sand for making the most perfect cement; but, with a little attention, it is evident that all prescribed rules must be so very vague and uncertain, as to be of little utility to the workman; for, besides the variation which is occasioned by a more or less degree of calcination, it is a certain fact, that some kinds of limestone are much more pure, and contain a much smaller proportion of sand, than others; consequently, it would be absurd to say that pure lime requires as small a proportion of sand, when made into mortar, as that which originally contained in itself a large proportion.

The variation thus produced, in regard to the proportion of sand, is found to be extremely great. It is, however, stated that the best mortar which has come under examination was formed of eleven parts of sand to one of lime; to which was added, by measure, between twice and thrice its own bulk of sand, which may be allowed to have been at least three times its quantity by weight. Supposing, therefore, that every particle of the lime had been so perfectly calcined as to be in a caustic state, there could not be less than forty-seven parts of sand to one of lime; but it is hard to suppose that above one hundredth part of this mass, independent of the water, consisted of pure caustic calcareous earth.

From these considerations, it is conceived that it is impossible to prescribe any determinate proportion of sand to lime, as that must vary according to the nature of the lime and other incidental circumstances, which would form an infinity of exceptions to any general rule. But it would seem that it might be safely inferred that the moderns, in general, rather err in giving too little, than in giving too much, sand. It deserves, however, to be noticed, that the sand, when naturally in the limestone, is more intimately blended with the lime than can possibly be

ever effected by any mechanical operation; so that it would be in vain to hope to make equally good mortar artificially from pure lime, with so small a proportion of caustic calcareous matter, as may sometimes be effected, when the lime naturally contains a very large proportion of sand. Still, however, there seems to be no doubt, that if a much larger proportion of sand than is common were employed, and that more carefully and expeditiously blended and worked, the mortar would be made much more perfect, as has been proved by actual experiments.

Another circumstance, which greatly tends to vary the quality of cement and to make a greater or smaller proportion of sand necessary, is the mode of preparing the lime before it is beaten up into mortar. When for plaster, it is of great importance to have every particle of the limestone slaked before it is worked up; for, as smoothness of surface is the most material point, if any particles of lime be beaten up before sufficiently slaked, the water still continuing to act on them, will cause them to expand, which will produce those excrescences on the surface of the plaster termed *blisters.* Consequently, in order to obtain a perfect kind of plaster, it is absolutely necessary that the lime, before being worked, be allowed to remain a considerable time macerating or *souring* in water: the same sort of process, though not absolutely required, would considerably improve the lime intended for mortar. Great care is required in the management, the principal thing being the procuring of well-burnt lime, and allowing no more lime, before worked, than is just sufficient to macerate or *sour* it with the water: the best-burnt lime will require the maceration of some days.

It has been almost universally admitted, that the hardest limestone affords the lime which will consolidate into the finest cement; hence, it is generally concluded that lime made of chalk produces a much weaker cement than that made of marble or limestone. It would seem, however, that, if ever this be the case, it is only incidentally, and not necessarily. In making the mortar, other substances are occasionally mixed with lime, which we shall here proceed to notice, and endeavor to point out their excellences and defects. Those commonly used, besides sand of various denominations, are powdered sandstone, brickdust, and sea shells; and for forming plaster where closeness, rather than hardness, is required, lime which has been slaked, and kept in a dry place till it has become nearly effete, and powdered chalk, or whiting, and gypsum, in various proportions, besides hair and other materials of a similar nature. Other ingredients have been more lately recommended, such as earthy balls, slightly burnt and pounded, old mortar rubbish, powdered and sifted, and various things of the like kind, the whole of which are, in some respect or other, objectionable.

Plaster of Paris is employed by the plasterer to give the requisite form and finish to all the superior parts of his work. It is made of a fossil stone called gypsum, which is excavated in several parts of the neighborhood of Paris, where it derives its name, and is calcined to a powder, to deprive it of its water of crystallization.

The stones are burnt in kilns, which are generally of very simple construction, being not unfrequently built of the gypsum itself. The pieces to be calcined are loosely put together in a parallelopiped heap, below which are vaulted pipes or flues, for the application of a moderate heat.

The calcination must not be carried to excess, as otherwise the plaster will not form a solid mass when mixed with a certain portion of water. During the process of calcination, the water of crystallization rises as white vapor, which, if the atmosphere be dry, is quickly dissolved in air.

The pounding of the calcined fragments is performed sometimes in mills constructed for the purpose, and sometimes by men, whose health is much impaired by the particles of dust settling upon their lungs.

On the River Wolga, in Russia, where the burning of gypsum constitutes one of the chief occupations of the peasantry, all kinds of gypsum are burnt promiscuously on grates made of wood; afterwards, the plaster is reduced to powder, passed through a sieve, and finally formed into small, round cakes, which are sold at so much per thousand.

These balls are reduced into an impalpable powder by the plasterer, and then mixed with mortar.

The less the gypsum is mixed with other substances, the better it is qualified for the purpose of making casts, stucco, &c. The sparry gypsum, or selenite, which is the purer kind, is employed for taking impressions from coins and medals, and for making those beautiful imitations of marble, granite, and porphyry, known by the name of *scagliola,* which is derived from the Italian word *scagli.*

Finely-powdered alabaster, or plaster of Paris, when heated in a crucible, assumes the appearance of a fluid, by rolling in waves, yielding to the touch, steaming, &c., all of which properties it again loses on the departure of the heat. If taken from the crucible and thrown upon paper, it will not wet it, but immediately be as motionless as it was before being exposed to the heat.

Two or three spoonfuls of burnt alabaster mixed up thin with water will, at the bottom of a vessel filled with water, coagulate into a hard lump, notwithstanding the water that surrounds it. The coagulating or setting property of burnt alabaster will be very much impaired or lost if the powder be kept for any considerable time, and more especially in the open air. When it has been once tempered with water, and suffered to grow hard, it cannot be rendered of any further use.

Plaster of Paris, diluted with water into the consistence of a soft or thin paste, quickly sets, or grows firm, and, at the instant of its setting, has its bulk increased. This expansive property, in passing from a soft to a firm state, is one of its valuable properties, rendering it an excellent matter for filling cavities in sundry works, where other earthy mixtures would shrink and leave vacuities, or entirely separate from the adjoining parts. It is also probable that this expansion of the plaster might be made to contribute to the elegance of the impressions it receives from medals, &c., by properly confining it when soft, so that, at its expansion, it would be forced into the minutest traces of the figures.

Other cements are used by plasterers for inside work. The first is called *lime and hair*, or *coarse stuff*, and is prepared as common mortar, with the addition of hair from the tan yards. The mortar is first mixed with a requisite quantity of sand, and the hair is afterwards worked in by the application of a rake.

Next to this is *fine stuff*, which is merely pure lime, slaked first with a small quantity of water, and afterwards, without any extraneous addition, supersaturated with water, and put into a tub in a half fluid state, where it is allowed to remain till the water is evaporated. In some particular cases, a small portion of hair is incorporated. When this fine stuff is used for inside walls, it is mixed with very fine washed sand, in the proportion of one part sand to three parts of fine stuff, and is then called *trowelled* or *bastard stucco*, with which all walls intended to be painted are finished.

The cement called *gauge stuff* consists of three fifths of fine stuff and one fifth plaster of Paris, mixed together with water, in small quantities at a time, to render it more ready to set. This composition is mostly used in forming cornices and mouldings run with a wooden mould. When great expedition is required, plasterers gauge all their mortars with plaster of Paris, which sets immediately.

MASTIC CEMENT.

This useful invention consists in making a cement or composition, which may be applied in the formation of ornaments and statues, and of bricks, or an imitation of bricks, tiles, and stones, and joining and cementing the same, and in erecting, covering, and decorating buildings internally and externally; and the said cement or composition may be mixed and moulded upon any sort of material, and whole and entire erections and substances may be worked and moulded therewith.

The cement consists in a mixture of earths and other substances that are insoluble in water, or nearly so, either in their natural state, or such as have been manufactured, as earthen ware, porcelain, and such like substances; but it is preferred that those earths, either in their natural or manufactured state, are the least soluble in water, and have, when pulverized, or reduced to powder, the least color. To the earth or earths as before named, either in their natural or manufactured state, and so pulverized, add a quantity of each of the oxides of lead, as litharge, gray oxide, and minium, reduced or ground to powder, and to the whole of the above-named substances a quantity of pulverized glass or flint stone.

These various earths, oxides, and glass, or flint stone, reduced to a pulverized state, in proper and due proportions, and being mixed with a proper and due proportion of vegetable oil, as hereinafter named, form and make a composition or cement, which, by contact or exposure to the atmosphere, hardens and forms an impenetrable and impervious coating or covering, resembling Portland or other stones.

The cement or composition is composed in the following manner and proportions: To any given

weight of earth or earths, commonly called pit sand, river sand, rock sand, or any other sand of the same or like nature, or pulverized earthen ware, or porcelain, add two thirds of such given weight of the earth or earths commonly called Portland stone, Bath stone, or any other stone of the same or like nature, pulverized. To every five hundred and sixty pounds' weight of these earths so prepared add forty pounds' weight of litharge, prepared as before described, and, with the last-mentioned given weights, combine two pounds' weight of pulverized glass or flint stone.

Then join to this mixture one pound weight of minium and two pounds' weight of gray oxide of lead.

This compound of earths, oxide, and glass, or flint stone, put into a circular or other proper machine, that will, by its rotary or other motion, mix them well, and their proper intermixture may be ascertained by the shade or colors, which should appear of one even and regular shade or hue; but any particular shade or color may be given by a proper selection of earths, or by adding a small quantity of vegetable, mineral, or other coloring matter.

This composition being thus mixed, pass the same through a wire sieve, or dressing machine, of such fineness or mash as may be requisite for the purposes it is intended for, preferring a fine sieve, mash or wire work, when the composition is to be used for works of a fine or even surface. The composition thus formed and mixed is a fine dry powder, and may be kept open in bulk or in casks for any length of time without deterioration.

When this composition is intended to be made into cement for any of the purposes described, it is spread upon a board or platform, or mixed in a trough; and to every six hundred and five pounds' weight of the composition are added five gallons of vegetable oil, as linseed oil, walnut oil, or pink oil.

The composition is then mixed in a similar way to that of the mortar, and is afterwards subjected to a gentle pressure by treading upon it; and this operation is continued until it acquires the appearance of moistened sand. The mixture being thus composed is a cement fit and applicable to the enumerated purposes. It is requisite to observe, that this cement should be used the same day the oil is added, otherwise it will fix or set into a solid substance, and be unfit for use.

When this cement is to be used or applied to any thing, — to making of decorations, ornaments, and statues, or artificial bricks, tiles, and stones, — running or casting moulds, prepared, suited, and applicable for the purposes for which they are intended, are made use of. The moulds for making ornaments, statues, or other fancy works are prepared and made of gypsum, or plaster of Paris, or seasoned or dry wood, and must be prepared by rubbing the internal parts well with raw linseed oil, until they are brought to a dry, smooth, and polished surface, to prevent adhesion; and in some instances, to obtain a more perfect, dry, smooth, and polished surface, pulverized plumbago is used. In all cases it is requisite to detach or remove, with convenient speed, the mould from the body of the cement or composition to which it is intended to give form.

The statue, ornament, bricks, tiles, and stones, or the imitations of all or either of them, thus formed, must be removed with care, and placed upon a bench or platform, which must be previously covered with fine dry sand to prevent adhesion; and, in some cases, for statues and ornaments, a bed of fine dry sand is necessary to receive them, where they must remain in both cases for the purpose of setting for twenty-four hours, or a longer period, according to the temperature to which they are exposed.

When it is applied for the purpose of cementing and joining of bricks, tiles, stones, and other substances, the surfaces to which the cement or composition is to be applied are prepared by brushing and cleaning them from dust and all loose matter; the said surfaces are then covered with boiled linseed oil, with a brush, as in painting. This application of the boiled linseed oil prevents the too rapid absorption of the oil employed or mixed with the cement or composition. A thin coating of the cement is then applied between the two bodies to be joined. When the cement is used for the purpose of covering buildings intended to resemble stone, the surface of the buildings is washed in oil.

The cement is then applied of the thickness of a quarter of an inch, or any greater thickness, according to the nature of the work, joint, or stone it is intended to resemble.

It is requisite to observe, that when a joint, intended to resemble a plain stone joint, is to be made upon the surface of the cement or composition, the cement or composition must be partly set or hardened previously to the impression of the joint upon its surface, and the joint is made by a rule and steel jointer.

When the cement is used for the covering of substances less absorbent than bricks, or tiles, (as wood, lead, iron, or tin,) a much less quantity of boiled linseed oil in preparing the surfaces is required.

LATHING, PLASTERING, &c.

Lathing, the first operation, consists in nailing laths on the ceiling or partition. Laths are made of spruce or pine, and are fastened with cut nails. They are made in four-foot lengths; and, with respect to their thickness and strength, are either single, lath and half, or double. The single are the thinnest and cheapest; those called *lath and half* are supposed to be one third thicker than the single; and the double laths are twice that thickness. In lathing ceilings, the plasterers should so dispose them that the joints be as much broken as possible, that they may have the stronger key or tie, and thereby strengthen the plastering with which they are to be covered. The thinnest laths are used in partitions, and the strongest for ceilings.

Laths are also distinguished into heart and sap laths: the former should always be used in plain tiling; the latter, which are of inferior quality, are most frequently used by the plasterer.

Sawed laths have within a few years been introduced, and are now in general use. They are not subject to so much waste, cost less, and do not require so much mortar as the split lath; the last named, however, retains the mortar most firmly.

Having nailed the laths in their appropriate order, the plasterer's next business is to cover them with plaster, the most simple and common operation of which is *laying;* that is, spreading a single coat of lime and hair over the whole ceiling or partition, carefully observing to keep it smooth and even in every direction. This is the cheapest kind of plastering.

Pricking up is performed in the same manner as the foregoing; but it is only a preliminary to a more perfect kind of work. After the plaster is laid on, it is crossed all over with the end of a lath, to give it a tie or key to the coat which is afterwards to be laid upon it.

Lathing, laying, and set, or what is termed *lath and plaster, one coat and set*, is, when the work, after being lathed, is covered with one coat of lime and hair, and afterwards, when sufficiently dry, a thin and smooth coat is spread over it, consisting of lime only, or, as the workmen call it, *putty* or *set.* This coat is spread with a smoothing trowel, used by the workman with his right hand, while his left hand moves a large flat brush of hogs' bristles, dipped in water, backwards and forwards over it, and thus produces a surface tolerably even for cheap work.

Lathing, floating and set, or *lath and plaster, one coat, floated and set*, differs from the foregoing, in having the first coat pricked up to receive the set, which is here called the *floating.* In doing this, the plasterer is provided with a substantial straight edge, frequently from ten to twelve feet in length, which must be used by two workmen. All the parts to be floated are tried by a straight edge, to ascertain whether they be perfectly flat and level; and whenever any deficiency appears, the hollow is filled up with a trowel full or more of lime and hair only, which is termed *filling out;* and when these preliminaries are settled, the screeds are next formed. The term *screed* signifies a style of lime and hair, about seven or eight inches in width, gauged quite true, by drawing the straight edge over it until it be so. These screeds are made at the distance of about three or four feet from each other, in a vertical direction, all round the partitions and walls of a room. When all are formed, the intervals are filled up with lime and hair, called by the workmen *stuff*, till flush with the face of the screeds. The straight edge is then worked horizontally on the screeds, by which all the superfluous stuff projecting beyond them in the intervals is removed, and a plain surface produced. This operation is termed *floating*, and may be applied to ceilings as well as to partitions or upright walls, by first forming the screeds in the direction of the breadth of the apartment, and filling up the intervals as above described. As great care is requisite to render the plaster sound and even, none but skilful workmen should be employed.

The *set* to floated work is performed in a mode similar to that already prescribed for *laying;* but, being employed only for best rooms, is done with more care. About one sixth of plaster of Paris is added to it, to make it set more expeditiously, to give it a closer and more compact appearance, and to render it more firm, and better calculated to receive the whitewash or color when dry. For floated

stucco work, the pricking up cannot be too dry; but if the floating which is to receive the setting coat be too dry before the set is laid on, there will be danger of its peeling off, or of assuming the appearance of little cracks or shells, which would disfigure the work. Particular care and attention, therefore, must be paid to have the under coats in a proper state of dryness. It may here be observed, that cracks, and other unpleasant appearances in ceilings, are more frequently the effect of weak laths being covered with too much plaster, or too little plaster upon strong laths, rather than of any sagging or other inadequacy in the timbers or the building. If the laths be properly attended to, and the plaster laid on by a careful and judicious workman, no cracks or other blemishes are likely to appear.

The next operation combines both the foregoing processes, but requires no lathing; it is called *rendering and set*, or *rendering, floated, and set.* What is understood by *rendering*, is the covering of brick or stone wall with a coat of lime and hair, and by *set* is denoted a superficial coat of fine stuff or putty upon the rendering. These operations are similar to those described for setting of ceilings and partitions; and the *floated and set* is laid on the rendering in the same manner as on the partitions, &c., already explained, for the best kind of work.

Trowelled stucco, which is a very neat kind of work, used in dining-rooms, halls, &c., where the walls are prepared to be painted, must be worked upon a floated ground, and the floating be kept quite dry before the stucco is applied. In this process, the plasterer is provided with a wooden tool, called a *float*, consisting of a piece of half-inch board, about nine inches long and three wide, planed smooth, with its lower edges a little rounded off, and having a handle on the upper surface. The stucco is prepared as above described, and afterwards beaten and tempered with clear water. The ground intended to be stuccoed is first prepared with a large trowel, and is made as smooth and level as possible; when the stucco has been spread upon it to the extent of four or five feet square, the workman, with a float in his right hand and a brush in his left, sprinkles with water and rubs alternately the face of the stucco, till the whole is reduced to a fine, even surface. He then prepares another square of the ground, and proceeds as before, till the whole is completed. The water has the effect of hardening the face of the stucco. When the floating is well performed, it will feel as smooth as glass.

Rough casting, or *rough walling*, is an exterior finishing, much cheaper than stucco, and, therefore, more frequently employed on cottages, farm-houses, &c., than on buildings of a higher class. The wall intended to be rough cast is first picked up with a coat of lime and hair; and when this is tolerably dry, a second coat is laid on, of the same materials as the first, as smooth as it can possibly be spread. As fast as the workman finishes this surface, he is followed by another with a pailful of rough cast, with which he bespatters the new plastering, and the whole dries together. The rough cast is composed of fine gravel, washed from all earthy particles, and mixed with pure lime and water, till the whole is of a semi-fluid consistency. This is thrown from the pail upon the wall with a wooden float, about five or six inches long, and as many wide, made of half-inch board, and fitted with a round handle. While, with this tool, the plasterer throws on the rough cast with his right hand, he holds in his left a common whitewasher's brush, dipped in the rough cast also, with which he brushes and colors the mortar and the rough cast he has already spread, to give them, when finished, a regular, uniform color and appearance.

Cornices are either plain or ornamented, and sometimes embrace a portion of both classes. The first point to be attended to is, to examine the drawings, and measure the projections of the principal members, which, if projecting more than seven or eight inches, must be bracketed. This consists in fixing up pieces of wood at the distance of about ten or twelve inches from each other, all round the place proposed for the cornice, and nailing laths to them, covering the whole with a coat of plaster. In the brackets, the stuff necessary to form the cornice must be allowed, which, in general, is about one inch and a quarter. A beech mould is next made by the carpenter, of the profile of the intended cornice, about a quarter of an inch in thickness, with the quirks, or small sinkings, of brass or copper. All the sharp edges are carefully removed by the plasterer, who opens with his knife all the points which he finds incompetent to receive the plaster freely.

These preliminaries being adjusted, two workmen, provided with a tub of putty and a quantity of plaster of Paris, proceed to run the cornice. Before using the mould, they gauge screed of putty and

plaster upon the wall and ceiling, covering so much of each as will correspond with the top and bottom of the intended cornice. On this screed, one or two slight board straight edges, adapted to as many notches or chases, made in the mould for it to work upon, are nailed. The putty is then mixed with about one third of plaster of Paris, and brought to a semi-fluid state by the addition of clean water. One of the workmen, with two or three trowels full of this composition upon his *hawk*, which he holds in his left hand, begins to plaster over the surface intended for the cornice, with his trowel, while his partner applies the mould to ascertain when more or less is wanted. When a sufficient quantity of plaster is laid on, the workman holds his mould firmly against both the ceiling and the wall, and moves it backwards and forwards, which removes the superfluous stuff, and leaves an exact impression of the mould upon the plaster. This is not effected at once; for while he works the mould backwards and forwards, the other workman takes notice of any deficiencies, and fills them up by adding fresh supplies of plaster. In this manner, a cornice from ten to twelve feet in length may be formed in a very short time; indeed, expedition is essentially requisite, as the plaster of Paris occasions a very great tendency in the putty to set; to prevent which, it is necessary to sprinkle the composition frequently with water, as plasterers, in order to secure the truth and correctness of the cornice, generally endeavor to finish all the lengths or pieces between any two breaks or projections at one time. In cornices which have very large proportions, and in cases where any of the orders of architecture are to be introduced, three or four moulds are required, and are similarly applied, till all the parts are formed. Internal and external mitres, and small returns or breaks, are afterwards modelled and filled up by hand.

Cornices to be enriched with ornaments have certain indentations, or sinkings, left in the mould in which the casts are laid. These ornaments were formerly made by hand, but now are cast in plaster of Paris, from clay models. When the clay model is finished, and has, by exposure to the action of the atmosphere, acquired some degree of firmness, it is let into a wooden frame, and, when it has been retouched and finished, the frame is filled with melted wax, which, when cold, is, by turning the frame upside down, allowed to fall off, being an exact cameo, or counterpart of the model. By these means, the most enriched and curiously-wrought mouldings may be cast by the common plasterer. These wax models are contrived to cast about a foot in length of the ornament at once, such lengths being easily got out from the cameo. The casts are made of the finest and purest plaster of Paris, saturated with water; and the wax mould is oiled previously to its being put in. When the casts or intaglios are first taken from the mould, they are not very firm; but being suffered to dry a little, either in the open air or in an oven, they acquire sufficient hardness to allow of being scraped and cleaned.

Basso rilievos and friezes are executed in a similar manner, only the wax mould is so made that the cast can have a back ground at least half an inch thick of plaster cast to the ornament or figure, in order to strengthen and secure the proportions, at the same time that it promotes the general effect.

The process for capitals to columns is also the same, except that numerous moulds are required to complete them. In the Corinthian capitals, a shaft or belt is first made, on which is afterwards fixed the foliage and volutes, the whole of which require distinct cameos.

In running cornices, which are to be enriched, the plasterer takes care to have proper projections in the running moulds, so as to make a groove in the cornice for the reception of the cast ornament, which is laid in and secured by spreading a small quantity of liquid plaster of Paris on its back. Detached ornaments intended for ceilings or other parts, and where no running mould has been employed, are cast in pieces corresponding with the design, and fixed upon the ceiling, &c., with white lead, or with the composition known by the name of *iron cement.*

The manufacture of stucco has, for a long time past, attracted the attention of all connected with this branch of building, as well as chemists and other individuals; but the only benefit resulting from such investigations is, a more extensive knowledge of the materials used. It would seem that the great moisture of our climate prevents its being brought to any high degree of perfection; though, among the various compositions which have been tried and proposed, some, comparatively speaking, are excellent.

Common stucco, used for external work, consists of clean-washed river sand and ground lime, which are mixed dry, in the proportion of three of the latter to

one of the former: when well incorporated together, these should be secured from the air in casks till required for use. Walls to be covered with this composition must first be prepared, by raking the mortar from the joints, and picking the bricks or stones, till the whole is indented; the dust and other extraneous matter must then be brushed off, and the wall well saturated with clean water. The stucco is supersaturated with water till it has the appearance and consistence of ordinary whitewash, in which state it is rubbed over the wall with a flat brush of hogs' bristles. When this process, called *roughing in*, has been performed, and the work has become tolerably dry and hard, which may be known by its being more white and transparent, the screeds are to be formed upon the wall with fresh stucco from the cask, tempered with water to a proper consistency, and spread on the upper part of the wall, about eight or nine inches wide; as also against the two ends, beginning at the top, and proceeding downwards to the bottom. In this operation, two workmen are required; one to supply the stucco, the other to apply the plumb rule and straight edge. When these are truly formed, other screeds must be made in a vertical direction, about four or five feet apart, unless apertures in the wall prevent it; in which case, they must be formed as near together as possible. When the screeding is finished, compo * is prepared in larger quantities, and both the workmen spread it with their trowels over the wall, in the space left between each pair of screeds. When this operation is complete, the straight edge is applied, and dragged from the top to the bottom of each pair, to remove whatever superfluous stucco may project above the screeds. If there be any hollow places, fresh stucco is applied, and the straight edge is again drawn over the spot, till the compo is brought even to the face of the screeds, and the whole is level with the edge of the rule. Another interval is then filled up, and the workmen thus proceed till the whole of the wall is covered. The wall is finished by floating; that is, hardening the surface by sprinkling it with water, and rubbing it with the common wood float, which is performed similarly to trowelling stucco.

This description of compo is frequently used by plasterers for cornices and mouldings, in the same manner as described in common plastering; but if the workman finds it necessary, he may add a small quantity of plaster of Paris, to make it fix the better while running or working the mould. Such addition is not, however, calculated to give strength to the stucco, and is only made through the necessity of having a quick set.

Scagliola is a distinct branch of plastering, discovered or invented, and much used, in Italy, and thence introduced into France, where it obtained its name.

Columns and pilasters are executed in this branch of plastering in the following manner: A wooden cradle, composed of thin strips of pine or other wood, is made to represent the column designed, but about two inches and a half less in diameter than the shaft is intended to be when finished. This cradle is lathed round, as for common plastering, and then covered with a pricking-up coat of lime and hair. When this is quite dry, the artists in scagliola commence operations, by imitations of the most rare and precious marbles, with astonishing and delusive effect; indeed, as the imitation takes as high a polish, and feels as cold and hard, as the most compact and solid marble, nothing short of actual fracture can possibly discover the counterfeit.

In preparing the scagliola, the workman selects, breaks, and calcines the purest gypsum, and as soon as the largest fragments, in the process of calcination, lose their brilliancy, withdraws the fire, and passes the calcined powder through a very fine sieve, and mixes it, as required for use, with a solution of glue, isinglass, &c. In this solution, the colors required in the marble to be imitated are diffused; but when the work is to be of various colors, each color is prepared separately, and afterwards mingled and combined, nearly in the same manner as a painter mixes on his palette the primitive colors to compose his different tints.

When the powdered gypsum is prepared, it is laid on the shaft of the intended column, over the pricked-up coat of lime and hair, and is then floated with moulds of wood, made to the requisite size: the artist uses the colors necessary to the imitation during the floating, by which means they mingle and incorporate with the surface. To obtain the glossy lustre, so much admired in works of marble, the workman rubs the work with one hand with a pumice stone, while with the other he cleans it with a wet sponge; he next polishes it with tripoli, charcoal, and a piece

* A name often given to Parker's cement.

of fine linen; afterwards with a piece of felt, dipped in a mixture of oil and tripoli; and finally completes the work by the application of pure oil. This imitation is, certainly, the most complete that can be conceived; and when the bases and capitals are made of real marble, as is the common practice, the deception is beyond discovery. If not exposed to the weather, it is, in point of durability, little inferior to real marble, retains its lustre full as long, and is not one eighth of the expense of the cheapest kind.

There is another species of plastering, used in the decorative parts of architecture, and for the frames of pictures, looking-glasses, &c., which is a perfectly distinct branch of the art. This composition, which is very strong, and, when quite dry, of a brownish color, consists of the proportion of two pounds of powdered whiting, one pound of glue in solution, and half a pound of linseed oil, mixed together, and heated in a copper, and stirred with a spatula till the whole is incorporated. When cool, it is laid upon a stone, covered with powdered whiting, and beaten till it assumes a tough and firm consistence; after which it is covered with wet cloths, to keep it fresh till required for use.

The ornaments to be cast in this composition are modelled in clay, as in common plastering, and afterwards a cameo, or mould, is carved in boxwood. This carving requires to be done with the utmost care, otherwise the symmetry of the ornament which is to be cast from it will be spoiled. The composition, when required for use, is cut with a knife into pieces of the requisite size and forced into the mould; after which it is put into a press worked by an iron screw, and still further compressed. When the mould is taken from the press, the composition, which is generally cast about a foot in length, is dislodged from the mould, and the superfluous parts pared off with a knife and cast into the copper for the next supply.

The ornaments thus formed are glued upon wooden grounds, or fixed by means of white lead, &c.; after which they are painted or gilt, according to the purposes for which they are intended. This composition is at least 80 per cent. cheaper than carving, and, in most cases, equally calculated to answer all the purposes of the art.

It is much to be wished, that the art of plastering could be restored to its ancient perfection, for the Romans possessed an art of rendering works of this kind much more firm and durable than can be accomplished at the present time.

The specimens of ancient Roman plastering still visible, which have not been injured by force, are found to be firm and solid, free from cracks or crevices, and as smooth and polished on the surface as when first applied. The sides and bottoms of the Roman aqueducts were lined with this plastering, and endured many ages.

At Venice, some of the roofs of houses and the floors of rooms are covered with a sort of plaster of later date, and yet strong enough to endure the sun and weather for several ages without either cracking or spoiling.

The method of making the Venetian composition is not known in England; but such might probably be made by heating the powder of gypsum over a fire, and when boiling, which it will do without the aid of water or other fluid, mixing it with rosin, or pitch, or both together, with common sulphur, and the powder of sea shells. If these be mixed together, water added to it, and the composition kept on the fire till the instant of its being used, it is not improbable that the secret may be discovered. Oil of turpentine and wax, which are the common ingredients in such cements as are accounted firmest, may also be tried as additions, as also may strong alewort, which is by some directed to be used instead of water, to make mortar of limestone of more than ordinary strength.

SLATING.

This branch of building, which is principally employed in the covering of roofs, is not unfrequently combined with that of plastering. The slates chiefly used in London are brought from the quarries at Bangor, in Caernarvonshire, which supply all parts of the United Kingdom. Another kind of slate, of a pale blue-green color, is used, and most esteemed, being brought from Kendal, in Westmoreland, called *Westmoreland slates.* These slates are not large, but of good substance, and well calculated to give a neat appearance to a roof. The Scottish slate, which assimilates in size and quality to a slate from Wales, called *ladies*, is in little repute.

The slates produced in this country are principally from the quarries in the State of Vermont. In point

of durability, they are equal to the Welsh slates, but have not that uniformity of color which distinguishes the latter.

The height of roofs at the present time is very rarely above one third of the span, and should never be less than one sixth. The most usual pitch for slates is that when the height is one fourth of the span, or at an angle of 26½ degrees with the horizon. Taking this as a standard, the following table will show the degree of inclination which may be given for other materials:—

Kind of Covering.	Inclination to the horizon. ° ′	Height of roof in parts of span.	Weight upon a square of roofing.
Copper, ...	3 50	$\frac{1}{48}$	100
Lead, ...	3 50	$\frac{1}{48}$	700
Slates, large, ...	22 00	$\frac{1}{5}$	1120
Slates, ordinary, . .	26 33	$\frac{1}{4}$	From 900 to 500
Stone slate, ...	29 41	$\frac{2}{7}$	2380
Plain tiles, ...	29 41	$\frac{2}{7}$	1780
Pan tiles, ...	24 00	$\frac{2}{9}$	650
Thatch of straw or reeds,	45 00	$\frac{1}{2}$	

Slaters class the Welsh and American slates in the following order:—

		Ft.	In.		Ft.	In.
Doubles,	average size,	1	1	by	0	6
Ladies,	" "	1	3	"	0	8
Countesses,	" "	1	8	"	0	10
Duchesses,	" "	2	0	"	1	0
Welsh rags,	" "	3	0	"	2	0
Queens,	" "	3	0	"	2	0
Imperials,	" "	2	6	"	2	0
Patent slate,	" "	2	6	"	2	0

The *doubles* are made from fragments of the larger kinds, and derive their name from their diminutive size. *Ladies* are similarly obtained. *Countesses* are a gradation above ladies; and *duchesses* above countesses.

Slate, like most other stony substances, is separated from its bed by the ignition of gunpowder. The blocks thus obtained are, by the application of wedges, reduced into layers, called *scantlings*, from four to nine inches in thickness, and of any required length and breadth, which are afterwards sawed to the respective sizes by machinery. The blue, green, and purple, or darker kinds of slate, are, in general, found capable of being split into very thin laminæ, or sheets; but those of the white or brownish freestone kind can seldom be separated or divided so fine; consequently, these last form heavy, strong, thick coverings, proper for buildings in exposed situations, such as barns, stables, and other outhouses.

The instruments used in splitting and cleaning slates are slate knives, axes, bars, and wedges; the three first being used to reduce the slates into the required thicknesses, and the last to remove the inequalities from the surface.

Imperial slating is particularly neat, and may be known by having its lower edge sawed; whereas, all other slates used for covering are chipped square on their edges only.

Patent slate was first brought into use by Mr. Wyatt, the architect; but a patent was never obtained. It derives its name from the mode adopted to lay it on the roofs; it may be laid on a rafter of much less elevation than any other, and is considerably lighter, by reason of the laps being less than is necessary for the common sort of slating. This slating was originally made from *Welsh rags;* but it is now very frequently made from *imperials*, which render it lighter, and also somewhat neater in appearance.

Westmoreland slate, from the experiments made by the late Bishop of Llandaff, appears to differ a little in its natural composition from that obtained from Wales. It must, however, be remarked, that this kind of slate owes its lightness, not so much to any diversity in the component parts of the stone, as to the thinness to which it is reduced by the workman; consequently, it is not so well calculated to resist violent winds as those which are heavier.

Slates, when brought from the quarry, are not sufficiently square for the slater's use; he therefore picks up and examines the slates separately, and observes which is the strongest and squarest end; then, seating himself, he holds the slate a little slanting upon, and projecting about an inch over, the edge of a small block of wood, which is of the same height as his seat, and cuts away and makes straight one of its edges; then, with a slip of wood, he gauges and cuts off the other edge parallel to it, and squares the end. The slate is now considered prepared for use, with the exception of perforating through its opposite ends two small holes for the reception of the nails which are to confine it to the

roof. Copper and zinc nails, or iron nails tinned, are considered the best, being less susceptible of oxidation than nails made of bar iron.

Before we proceed further with the operations necessary in the slating of buildings, we shall give some account of the tools used by this class of artificers.

Slaters' tools are very few, which sometimes are found by the masters, and sometimes by the men. The tool called the *saixe* is made of tempered iron, about sixteen inches in length, somewhat bent at one end, with a handle of wood at the other. This tool is not unlike a large knife, except that it has on its back a projecting piece of iron, about three inches in length, drawn to a sharp point. This tool is used to chip or cut all the slates to the required sizes.

The *ripper* is also of iron, about the same length as the *saixe;* it has a very thin blade, about an inch and three quarters wide, tapered somewhat towards the top, where a round head projects over the blade about half an inch on each side; it has also two little round notches in the two internal angles, at their intersections. The handle of this tool is raised above the blade by a shoulder, which enables the workman to hold it firm. This instrument is used in repairing old slating, and the application consists in thrusting the blade under the slates, so that the head, which projects, may catch the nail in the little notch at its intersection, and enable the workman to draw it out. During this operation, the slate is sufficiently loosened to allow of its being removed and another inserted in its place.

The *hammer*, which is somewhat different in shape to the ordinary tool of that name, is about five inches in height on the hammer or driving part, and the top is bent back, and ground to a tolerably sharp point, its lower or flat end, which is quite round, being about three quarters of an inch in diameter. On this side of the driving part is a small projection, with a notch in the centre, which is used as a claw to extract such nails as do not drive satisfactorily.

The *shaving tool* is used for getting the slates to a smooth face for skirtings, floors for balconies, &c. It consists of an iron blade, sharpened at one of its ends like a chisel, and mortised through the centre of two round wooden handles, one fixed at one end, and the other about the middle of the blade. The blade is about eleven inches long and two inches wide, and the handle is about ten inches long; so that they project about four inches on each side of the blade. In using this tool, the workman places one hand on each side of the handle that is in the middle of the blade, and allows the other to press against both his wrists. In this manner, he removes all the uneven parts from off the face of the slate, and gets it to a smooth surface.

The other tools used by the slater consist of chisels, gouges, and files of all sizes; by means of which he finishes the slates into mouldings and other required forms.

In slating roofs, it is necessary to form a base or floor for the slates to lay compactly and safely upon; for *doubles* and *ladies*, boarding is required, which must be laid very even, with the joints close, and properly secured by nails to the rafters. This being completed, the slater provides himself with several slips of wood, called *tilting fillets*, about ten inches and a half wide, and three quarters of an inch thick on one edge, and chamfered to an arris on the other, which he nails down all round the extreme edges of the roof, beginning with the hips, if any, and if not, with the sides, eaves, and ridge. He next selects the largest of the slates, and arranges them regularly along the eaves, with their lower edges to a line, and nails them to the boarding. This part of the work being completed, he takes other slates to form the bond to the under sides of the eaves, and places them under those previously laid, so as to cross and cover all their joints. Such slates are pushed up lightly under those which are above them, and are seldom nailed, but left dependent for support on the weight of those above them, and their own weight on the boarding. The *countesses* and all other descriptions of slates, when intended to be laid in a good manner, are also laid on boards.

When the slater has finished the eaves, he stretches a line on the face of the upper slates, parallel to its outer edge, and as far from it as he deems sufficient for the lap of those he intends shall form the next course, which is laid and nailed even with the line, crossing the joints of the upper slates of the eaves. This lining and laying is continued close to the ridge of the roof, observing throughout to break the different joints, by laying the slates one above another. The same system is universally followed in laying all the different sorts of slates, with the exception of those called *patent slates*, as hereafter explained.

The largest kind of slates are found to lay firm on

battens, which are, consequently, much employed, and produce a very considerable saving of expense in large buildings. A batten is a narrow portion of board, about two inches and a half or three inches wide, four of them being commonly procured from an eleven-inch board.

For countess slates, battens three quarters of an inch thick will be of adequate substance; but for the larger and heavier kinds, inch battens will be necessary. In battening a roof for slates, the battens are not placed at a uniform distance from each other, but so as to suit the length of the slates; and as these vary as they approach the apex or ridge of the roof, it follows that the slater himself is the best judge where to fix them, so as best to support the slates.

A roof, to be covered with patent slates, requires that the common rafters be left loose upon their purlines, as they must be so arranged that a rafter shall lie under every one of the meeting joints. Neither battening nor boarding is required for these slates. The number of rafters will depend on the width of the slates; hence, if they be of a larger size, very few will suffice. This kind of slating is likewise commenced at the eaves; but no crossing or bonding is required, as the slates are laid uniformly, with each end reaching to the centre of the rafter, and butted up to each other throughout the length of the roof. When the eaves-course is laid, the slates which compose it are screwed down to the rafters by two or three strong inch and half screws at each of their ends. A line is then strained about two inches below the upper edge, in order to guide the laying of the next course, which is laid with its lower edge touching the line. This lining, laying with a lap, and screwing down, is continued till the roof is completely covered. The joints are then secured by filleting, which consists in covering all the meeting joints with fillets of slate, bedded in glaziers' putty, and screwed down through the whole into the rafters. The fillets are usually about three inches wide, and of a length proportionate to that of the slates whose joints they have to cover. These fillets are solidly bedded in the putty, and their intersecting joints are lapped similar to those of the slates. The fillets being so laid, and secured by one in the middle of the fillet, and one in each lap, are next neatly pointed all round their edges with more putty, and then painted over with the color of the slate. The hips and ridges of such slating are frequently covered by fillets, which produce a very neat effect; but lead, which is not much dearer, is by far the best kind of covering for all hips and ridges. The patent slating may be laid so as to be perfectly water tight, with an elevation of the rafters considerably less than for any other slate or tile covering. The rise in each foot of length in the rafter is not required to be more than two inches, which, in a rafter of fifteen feet, will amount to only two feet six inches — a rise scarcely perceptible from the ground.

Slating is performed in several other ways, but the principles already explained embrace the most of them. Some workmen shape and lay their slates in a lozenge form. This kind of work consists in getting all the slates to a uniform size, of the shape of a geometrical square. When laid on the roof, which must be boarded, they are bonded and lapped as in common slating, observing only to let the elbow, or half of the square, appear above each slate that is next beneath it, and be regular in the courses all over the roof. One nail or screw only can be used for such slating; hence it soon becomes dilapidated. It is commonly employed in places near to the eye, or where particular neatness is required.

It has been ascertained that a slate one inch thick will, in a horizontal position, support as much in weight as five inches of Portland stone similarly suspended. Hence slates are now wrought and used in galleries, and other purposes, where it is essential to have strength and lightness combined. Slates are also fashioned into chimney-pieces, but are incapable of receiving a polish like marble. It makes excellent skirtings of all descriptions, as well as casings to walls, where dilapidations or great wear and tear are to be expected. For these purposes, it is capable of being fixed with joints, equally as neat as wood; and may, if required, be painted over so as to appear like it. Staircases may also be executed in slate, which will produce a resemblance of marble.

PLUMBING.

Plumbing is the art of casting and working in lead, and using the same in the covering and for other purposes in building.

To the plumber is also confided the pump work,

as well as the making and forming of cisterns and reservoirs, large or small closets, &c., for the purposes of domestic economy. The plumber does not use a great variety of tools, because the ductility of the metal upon which he operates does not require it.

The tools used consist of an iron hammer, rather heavier than a carpenter's, with a short, thick handle; two or three wooden mallets of different sizes, and a dressing and flatting tool. This last is of beech, about eighteen inches long and two inches square, planed smooth and flat on the under surface, and rounded on the upper, and one of its ends tapered off round as a handle. With this tool he stretches out and flattens the sheet lead, or dresses it to the shape required, using first the flat side, then the round one, as occasion may require.

The plumber has also occasion for a jack and trying plane, similar to that of the carpenter. With this he reduces the edges of sheet lead to a straight line, when the purposes to which it is to be applied require it. His cutting tools consist of a variety of chisels and gouges, as well as knives. The latter of these are used for cutting the sheet lead into slips and pieces after it has been marked out by the chalk line.

Files of different sizes; ladles of three or four sizes, for melting the solder; and an iron instrument called *grozing irons.*

These grozing irons are of several sizes, generally about twelve inches in length, tapered at both ends, the handle end being turned quite round, to allow of its being firmly held while in use; the other end is a bulb, of a spindle or spherical shape, of a size proportioned to the soldering intended to be executed. They are, when required for use, heated to redness.

The plumber's measuring rule is two feet in length, divided into three equal parts of eight inches each; two of its legs are of boxwood, duodecimally divided; and the third consists of a piece of slow-tempered steel, attached to one of the box legs by a pivot on which it turns, and falls, when not in use, into a groove cut in such leg for its reception. This steel leg can be passed into places where the others cannot enter; and it is also useful for occasionally removing the oxide or any extraneous matters from the surface of the heated metal.

Scales and weights are also necessary; and he must be supplied with centre bits of all sizes, for the purpose of making perforations in lead or wood, through which he may want to insert pipes, &c. Compasses, to strike circular pieces, to line or cover figures of that shape, are occasionally required.

Lead is obtained from ore, and, from its being generally combined with sulphur, it has been denominated *sulphuret.* After the ore has been taken from its bed it is smelted, first being picked, in order to separate the unctuous and rich or genuine ore from the stony matrice, and other impurities; the picked ore is then pounded under stampers worked by machinery, and afterwards washed to carry off the remainder of the matrice, which could not be separated in picking. It is next put into a reverberatory furnace to be *roasted;* during which operation it is repeatedly stirred, to facilitate the evaporation of the sulphur. When the surface begins to assume the appearance of a paste, it is covered with charcoal, and well shaken together; the fire is then increased, and the purified lead flows down on all sides into the basin of the furnace, whence it runs off into moulds prepared for its reception. The moulds are capable of receiving one hundred and fifty-four pounds of lead each, and their contents, when cool, are, in the commercial world, called *pigs.*

Lead is of a bluish-white color, and when newly melted, or cut, is quite bright; but it soon becomes tarnished on exposure to the atmosphere — assuming first a dirty, gray color, and afterwards becomes white. It is capable of being hammered into very thin plates, and may be drawn into wire; but its tenacity is very inferior to that of other metals, for a leaden wire, the hundred and twentieth part of an inch in diameter, is only capable of supporting about eighteen pounds without breaking. Lead, next to tin, is the most fusible of all metals; and if a stronger heat be applied, it boils and evaporates. If cooled slowly, it crystallizes. The change of its external color is owing to its gradual combination with oxygen, which converts its exterior surface into an oxide. This outward crust, however, preserves the rest of the metal for a long time, as the air can penetrate but very slowly.

Lead is not acted upon immediately by water, though that element greatly facilitates the action of the air upon it; for it is known that, when lead is exposed to the atmosphere, and kept constantly wet, the process of oxidation takes place much more rapidly than it does under other circumstances; hence the white crust that is to be observed on the sides of

leaden vessels containing water, just at the place where the surface of the water terminates.

Lead is purchased by plumbers in pigs, and they reduce it into sheets, or pipes, as they have occasion. Of sheet lead they have two kinds, cast and milled. The former is used for covering flat roofs of buildings, laying of terraces, forming gutters, lining reservoirs, &c.; and the latter, which is very thin, for covering the hips and ridges of roofs. This last they do not manufacture themselves, but purchase it of the lead merchants, ready prepared.

For the casting of sheet lead, a copper is provided, and well fixed in masonry, at the upper end of the workshop, near the mould or casting table, which consists of strong boards, well jointed together, and bound with bars of iron at the ends. The sides of this table, of which the shape is a parallelogram, vary in size from four to six feet in width, and from sixteen to eighteen feet and upwards in length, and are guarded by a frame or edging of wood, three inches thick, and four or five inches higher than the interior surface, called the *shafts*. This table is fixed upon firm legs, strongly framed together, about six or seven inches lower than the top of the copper. At the upper end of the mould, nearest the copper, is a box, called the *pan*, which is adapted in its length to the breadth of the table, having at its bottom a long, horizontal slit, from which the heated metal is to issue, when it has been poured in from the copper. This box moves upon rollers along the surface of the rim of the table, and is put in motion by means of ropes and pulleys, fixed to beams above. While the metal is melting, the surface of the mould, or table, is prepared by covering it with a stratum of dry and clean sand, regularly smoothed over with a kind of rake, called a *strike*, which consists of a board about five inches broad, and rather longer than the inside of the mould, so that its ends, which are notched about two inches deep, may ride upon the shafts. This being passed down the whole length of the table, reduces the sand to a uniform surface. The pan is now brought to the head of the table, close to the copper, its sides having previously been guarded by a coat of moistened sand, to prevent its firing from the heat of the metal, which is now put in by ladles from the copper.

These pans, or boxes, it must be observed, are made to contain the quantity of melted lead which is required to cast a whole sheet at one time; and the slit in the bottom is so adjusted as to let out, during its progress along the table, just as much as will completely cover it of the thickness and weight per foot required. Every thing being thus prepared, the slit is opened, and the box moved along the table, dispensing its contents from the top to the bottom, and leaving in its progress a sheet of lead of the desired thickness. When cool, the sheet is rolled up and removed from the table, and other sheets are cast, till all the metal in the copper is exhausted. The sheets thus formed are then rolled up and kept for use.

In some places, instead of having a square box upon wheels, with a slit in the bottom, the pan consists of a kind of trough, being composed of two planks nailed together at right angles, with two triangular pieces fitted in between them at their ends. The length of this pan, as well as that of the box, is equal to the whole breadth of the mould. It is placed with its bottom on a bench at the head of the table, leaning with one side against it; to the opposite side is fixed a handle, by which it may be lifted up in order to pour out the liquid metal. On the side of the pan next the mould are two iron hooks, to hold it to the table, and prevent it from slipping while the metal is being poured into the mould.

The mould, as well as the pan, is spread over about two inches thick with sand sifted and moistened, and rendered perfectly level by moving over it the strike, and smoothing it down with a plane of polished brass, about a quarter of an inch thick and nine inches square, turned up on the edges.

Before they proceed to casting the lead, the strike is made ready by tacking two pieces of old hat on the notches, or by covering the notches with leather cases, so as to raise the under side of the strike about an eighth of an inch or more above the sand, according to the proposed thickness of the sheet. The face or under side of the strike is then smeared with tallow, and laid across the breadth of the mould, with its ends resting on the shafts. The melted lead is then put into the pan with ladles; and, when a sufficient quantity has been put in, the scum is swept off with a piece of board, and suffered to settle on the coat of sand, to prevent its falling into the mould when the metal is poured out. It generally happens that the lead, when first taken from the copper, is too hot for casting; it is, therefore, suffered to cool in the pan till it begins to stand with a shell or wall on the sand with which the pan is lined. Two men then

take the pan by the handle, or one of them takes it by means of a bar or chain fixed to a beam in the ceiling, and turn it down, so that the metal runs into the mould; while another man stands ready with the strike, and, as soon as all the metal is poured in, sweeps it forward and draws the residue into a trough at the bottom, which has been prepared to receive it. The sheet is then rolled up as before.

In this mode of operation, the table inclines in its length about an inch or an inch and a half, in the length of sixteen or seventeen feet, or more, according to the required thickness of the sheets: the thinner the sheet, the greater the declivity; and *vice versa.* The lower end of the mould is also left open, to admit of the superfluous metal being thrown off.

When a cistern is to be cast, the size of the four sides is measured out; and the dimensions of the front having been taken, slips of wood, on which the mouldings are carved, are pressed upon the sand. Figures of birds, beasts, &c., are likewise stamped in the internal area, by means of leaden moulds. If any part of the sand has been disturbed in doing this, it is made smooth, and the process of casting goes on as for plain sheets; except that, instead of rolling up the lead when cast, it is bent into four sides, so that the two ends, when they are soldered together, may be joined at the back: the bottom is afterwards soldered up.

The lead which lines the Chinese tea boxes is reduced to a thinness which our plumbers cannot, it is said, approach. The following account of the process was communicated by an intelligent East Indian, in a letter which appeared in the Gentleman's Magazine: "The caster sits by a pot containing the melted metal, and has two large stones, the lower one fixed and the upper one movable, having their surfaces of contact ground to each other, directly before him. He raises the upper stone by pressing his foot upon its side, and with an iron ladle pours into the opening a sufficient quantity of the fluid metal. He then lets fall the upper stone, and thus forms the lead into an extremely thin and irregular plate, which is afterwards cut into its required form."

Cast sheet lead, used for architectural purposes, is technically divided into 5 lb., $5\frac{1}{2}$ lb., 6 lb., $6\frac{1}{2}$ lb., 7 lb., $7\frac{1}{2}$ lb., 8 lb., and $8\frac{1}{2}$ lb.; by which is understood that every superficial foot is to contain those respective weights, according to the price agreed upon.

The milled lead used by plumbers is very thin, seldom containing more than five pounds to the foot. It is by no means adapted to gutters or terraces, nor, indeed, to any part of a building that is much exposed either to great wear or to the effects of the sun's rays: in the former case, it soon wears away; in the latter, expands and cracks. It is laminated in sheets of about the same size as those of cast lead, by means of a roller, or flatting mill.

Lead pipes are sometimes made of sheet lead, by beating it on round wooden cylinders of the length and dimensions required, and then soldering up the edges.

Solder is used to secure the joints of work in lead, which, by other means, would be impossible. It should be easier of fusion than the metal intended to be soldered, and should be as nearly as possible of the same color. The plumber, therefore, uses what is technically called *soft solder*, which is a compound of equal parts of tin and lead, melted together and run into moulds. In this state it is sold by the manufacturer, by the pound.

In the operation of soldering, the surfaces or edges intended to be united are scraped very clean, and brought close up to each other, in which state they are held by an assistant, while the plumber applies a little resin on the joints, in order to prevent the oxidation of the metal. The heated solder is then brought in a ladle and poured on the joint; after which it is smoothed and finished by rubbing it about with a red-hot soldering iron; when completed, it is made smooth by filing.

In the covering of roofs or terraces with lead, (the sheets never exceeding six feet in breadth,) it becomes necessary, in large surfaces, to have joints, which are managed several ways, but in all the chief object is to have them water tight. The best plan of effecting this is to form *laps*, or roll joints, which is done by having a roll or strip of wood about two inches square, but rounded on its upper side, nailed under the joints of the sheets, where the edges lap over each other: one of these edges is to be dressed up over the roll on the inside, and the other is to be dressed over them both on the outside, by which means the water is prevented from penetrating. No other fastening is requisite than what is required from the hammering of the sheets together down upon the flat; nor should any other be resorted to when sheet lead is exposed to the vicissitudes of the weather, because it expands and shrinks, which, if

prevented by too much fastening, would cause it to crack and become useless. It sometimes, however, occurs, that rolls cannot be used, and then the method of joining by seams is resorted to. This consists in simply bending the approximate edges of the lead up and over each other, and then dressing them down close to the flat, throughout their length. But this is not equal to the roll, either for neatness or security.

Lead flats and gutters should always be laid with the current, to keep them dry. About a quarter of an inch to the foot is a sufficient inclination.

In laying gutters, &c., pieces of milled lead, called *flushing*, about eight or nine inches wide, are fixed in the walls, all round the edges of the sheet lead, with which the flat is covered, and are suffered to hang down over them, so as to prevent the passage of rain through the interstice between the raised edge and the wall. If the walls have been previously built, the mortar is raked out of the joint of the bricks next above the edge of the sheet, and the flushings are not only inserted into the crack at the upper sides, but their lower edges are likewise dressed over those of the lead in the flat, or gutter. When neither of these modes can be resorted to, the flushings are fastened by wall hooks, and their lower edges dressed down as before.

Drips in flats, or gutters, are formed by raising one part above another, and dressing the lead, as already described, for covering the rolls. They are resorted to when the gutter or flat exceeds the length of the sheet; or, sometimes, for convenience. They are also a useful expedient to avoid soldering the joints.

Sheet lead is also used in the lining of reservoirs, which are made either of wood or masonry. As these conveniences are seldom in places subject to material changes of temperature, recourse may be had to the soldering without fear of its damaging the work, by promoting a disposition to crack.

The pumps which come under the province of the plumber are confined generally to two or three kinds used for domestic purposes, of which the suction and lifting pumps are the chief; these, as well as water closets, are manufactured by a particular set of workmen, and sold to the plumber, who furnishes the lead pipes, and fixes them in their places.

Plumbers' work is generally estimated by the pound, or hundred weight; but the weight may be discovered by measurement, in the following manner: Sheet lead used in roofing and guttering is commonly between seven and twelve pounds to the square foot; but the following table exhibits the particular weight of a square foot for each of the several thicknesses: —

Thickness.	lbs. to a sq. foot.	Thickness.	lbs. to a sq. foot.
.10	5.899	.15	8.848
.11	6.489	.16	9.438
$\frac{1}{9}$	6.554	$\frac{1}{6}$	9.831
.12	7.078	.17	10.028
$\frac{1}{8}$	7.373	.18	10.618
.13	7.668	.19	11.207
.14	8.258	$\frac{1}{5}$	11.797
$\frac{1}{7}$	8.427	.21	12.387

In this table, the thickness is set down in tenths and hundredths, &c., of an inch; and the annexed corresponding numbers are the weights in avoirdupois pounds and $\frac{1}{1000}$ of a pound; so that the weight of a square foot of $\frac{1}{10}$ in. thick, $\frac{10}{100}$, is $5\frac{899}{1000}$ pounds; and the weight of a square foot, $\frac{1}{9}$ in. in thickness, is $6\frac{554}{1000}$ pounds. Leaden pipe, of an inch bore, is commonly thirteen or fourteen pounds to the yard in length.

GLAZING.

The business of this class of artificers consists in putting glass into sashes and casements. Glaziers' work may be classed under three distinct heads — sash work, lead work, and fret work.

The tools requisite for the performances of the first of these departments are, a diamond, a ranging lathe, a short lathe, a square, a rule, a glazing knife, a cutting chisel, a beading hammer, duster, and sash tool; and, in addition, for stopping in squares, a hacking knife and hammer.

The diamond is a speck of that precious stone, polished to a cutting point, and set in brass on an iron socket, to receive a wooden handle, which is so set as to be held in the hand in the cutting direction. The top of the handle goes between the root of the forefinger and the middle finger, and the hinder part between the point of the forefinger and thumb; there is, in general, a notch in the side of the socket, which should be held next to the lathe. Some diamonds have more cuts than one. Plough diamonds have a square nut on the end of the socket next the glass, which, on running the nut square on the side of the lathe, keeps it in the cutting direction. Glass grinders have these plough diamonds without long handles,

as, in cutting their curious productions, they cannot apply a lathe, but direct them by the point of their middle finger, gliding along the edge of the glass.

The ranging lathe must be long enough to extend rather beyond the boundary of the table of glass.

Ranging of glass is the cutting it in breadths as the work may require, and is best done by one uninterrupted cut from one end to the other.

The square is used in cutting the squares from the range, that they may with greater certainty be cut at right angles. The glazing knife is used for laying in the putty in the rabbets of the sash, for binding in the glass, and for finishing the front putty.

Of the glass used in building, three qualities are in common use, denominated *best*, *second*, and *third*. The best is that which is the purest metal and free of blemishes, as blisters, specks, streaks, &c.; the second is inferior, from its not being so free from these blemishes; and the third is still inferior, both in regard to quality and color, being of greener hue. They are sold at the same price per crate; but the number of tables varies according to the quality. Best twelve, second fifteen, and third eighteen tables.

These tables are circular when manufactured, and about 4 feet in diameter, having in the centre a knot, to which, in the course of the process, the flashing rod was fixed; but for the safety of carriage and convenience of handling, as well as utility in practice, a segment is cut off about 4 inches from the knot. The large piece with the knot still retains the name of *table;* the smaller piece is technically called a *slab.* From these tables being of a given size, it is reasonable to suppose that, when the dimensions of squares are such as cut the glass to waste, the price should be advanced.

A superior kind of glass may be obtained at some of the first houses in London, which is very flat and of large dimensions, some of it being 2 feet 8 inches by 2 feet 1 inch; these are sold only in squares.

Rough glass is well adapted to baths and other places of privacy; one side is ground with emery or sand, so that no objects can be seen through it, though the light be still transmitted.

Plate glass is the most superior in quality, substance, and flatness, being cast in plates, and polished. The quantity of metal it contains must be almost, if not altogether, colorless; that sort which is tinged being of an inferior quality. Plate glass, when used in sashes, is peculiarly magnificent; and it can be had of larger dimensions than any other kind of glass.

Stained glass is of different color, as red, orange, yellow, green, blue, and purple. These colors are fixed by burning, and are as durable as the glass.

In this country, window glass is used of various sizes, from 7 inches by 9 inches to 12 by 20 inches. It is packed by the manufacturers in boxes, containing 50 or 100 square superficial feet. There are many manufactories of this article in the United States which usually produce glass of good quality; but the reputation of Boston plate glass stands decidedly higher than any other, either of foreign or domestic manufacture. The "New England Company," in Boston, manufacture stained glass in a style not surpassed in Europe.

Glass can be bent to circular sweeps, which is much used in London for shop windows, and is carried to great perfection in covers, for small pieces of statuary, &c.

The application of stained glass to the purposes of glazing is called *fretwork.* This description of work consists of working ground and stained glass, in fine lead, into different patterns. In many cases, family arms and other devices are worked in it. It is a branch capable of great improvement, but at present is much neglected. Old pieces are very much esteemed, though the same expense would furnish elegant modern productions. They are placed in halls and staircase windows, or in some particular church windows. In many instances, they are introduced where there is an unpleasant aspect, in a place of particular or genteel resort.

Lead work is used in inferior offices, and is in general practice all through the country. Frames intended to receive these lights are made with bars across, to which the lights are fastened by leaden bars, called *saddle bars;* and where openings are wanted, a casement is introduced either of wood or iron. Sometimes a sliding frame answers the same purposes. Church windows are generally made in this manner, in quarries or in squares.

The tools with which this work is performed are, in addition to the foregoing, as follows:—

A *vice*, with different checks and cutters, to turn out the different kinds of lead, as the magnitude of the window or the squares may require.

The German vices, which are esteemed the best, are furnished with moulds, and turn out lead in a variety of sizes. The bars of lead cast in these vices are received by the mill, which turns them out with two sides parallel to each other, and about $\frac{3}{8}$ of an inch broad, with a partition connecting the two sides together, about $\frac{1}{8}$ of an inch wide, forming on each side a groove, nearly $\frac{2}{6}$ by $\frac{1}{8}$ of an inch, and about 6 feet long.

Besides a vice and moulds, there are a setting board, latterkin, setting knife, resin box, tin, glazing irons, and clips.

The *setting board* is that in which the ridge of the light is marked and divided into squares, struck out with a chalk line, or drawn with a lathe, which serves to guide the workman. One side and end is squared with a projecting bead or fillet.

The *latterkin* is a piece of hard wood pointed, to run in the groove of the lead, and widen it for the easier reception of the glass.

The *setting knife* consists of a blade with a round point, loaded with lead at the bottom, and terminating in a long, square handle. The square end of the handle serves to force the square of glass tight in the lead. All the intersections are soldered on both sides, except the outside joints of the outer sides — that is, where they come to the outer edge. These lights should be cemented by pouring thin paint along the lead bars, and filling up the chasms with dry whiting, to which, after the oil in the paint has secreted a little, a little more dry whiting, or white lead, must be added. This will dry hard, and resist the action of the atmosphere.

PAINTING.

Painting, as applied to purposes of building, is the application of artificial colors, compounded either with oil or water, in embellishing and preserving wood, &c.

This branch of painting is termed *economical*, and applies more immediately to the power which oil and varnishes possess, of preventing the action of the atmosphere upon wood, iron, and stucco, by interposing an artificial surface; but it is here intended to use the term more generally, in allusion to the decorative part, and as it is employed by the architect, throughout every part of his work, both externally and internally.

In every branch of painting in oil, the general processes are very similar, or with such variations only as readily occur to the workman.

The first coatings, or layers, if on wood or iron, ought always to be of ceruse or white lead, of the best quality, previously ground very fine in nut or linseed oil, either over a stone with a muller, or, as that mode is too tedious for large quantities, passed through a mill. If used on shutters, doors, or wainscotings, made of pine, it is very requisite to destroy the effects of the knots, which are generally so completely saturated with turpentine as to render it, perhaps, one of the most difficult processes in this business. The best mode in common cases is to pass a brush over the knots with ceruse ground in water, bound by a size made of parchment or glue; when that is dry, paint the knots with white lead ground in oil, to which add some powerful siccative, or drier, as red lead, or litharge of lead; about one part of the latter. These must be laid very smoothly in the direction of the grain of the wood.

When the last coat is dry, smooth it with pumice stone, or give it the first coat of paint, prepared or diluted with nut or linseed oil; after which, when sufficiently dry, all the nail holes or other irregularities on the surface must be carefully stopped with a composition of oil and Spanish white, commonly known by the name of *putty*. The work must then be painted with white lead and oil, somewhat diluted with the essence of oil of turpentine, which process should, if the work be intended to be left of a plain white or stone color, be repeated not less than three or four times; and if of the latter color, a small quantity of ivory or lampblack should be added. But if the work is to be finished of any other color, either gray, green, &c., it will be requisite to provide for such color after the third operation, particularly if it is to be finished flat, or, as the painters style it, dead white, gray, fawn, &c. In order to finish the work flatted or dead, which is a mode much to be preferred for all superior works, not only for its appearance, but also for preserving the color and purity of the tint, one coat of the flatted color, or color mixed up with a considerable quantity of turpentine, will be found sufficient; although in large surfaces it will be frequently requisite to give two coats of the flatting color to make it quite complete. Indeed, on stucco it will be almost a general rule.

In all the foregoing operations, it must be observed

that some sort of drier is absolutely requisite; a very general and useful one is made by grinding in linseed, or perhaps prepared oils, boiled, are better, about two parts of the best white copperas, which must be well dried with one part of litharge of lead; the quantity to be added will much depend on the dryness or humidity of the atmosphere at the time of painting, as well as the local situation of the building. It may here be noticed, that there is a sort of copperas made in England, and said to be used for some purposes in medicine, that not only does *not* assist the operation of drying in the colors, but absolutely prevents these colors drying, which would otherwise have done so in the absence of the copperas.

The best drier for all fine whites and other delicate tints is sugar of lead, ground in nut oil; but being very active, a small quantity, about the size of a walnut, will be sufficient for twenty pounds of color, when the basis is white lead.

It does not appear that painting in oil can be serviceable in stucco, unless the walls have been erected a sufficient time to permit the mass of brick work to have acquired a sufficient degree of dryness. When stucco is on battened work, it may be painted over much sooner than when prepared on brick. Indeed, the greatest part of the art of painting stucco, so as to stand or wear well, consists in attending to these observations; for whoever has observed the expansive power of water, not only in congelation, but also in evaporation, must be well aware that when it meets with any foreign body obstructing its escape, as oil painting, for instance, it immediately resists it, forming a number of vesicles or particles, containing an acrid lime water, which forces off the layers of plaster, and frequently causes large defective patches, not easily to be eradicated.

Perhaps in general cases, where persons are building on their own estates or for themselves, two or three years are not too long to suffer the stucco to remain unpainted, though frequently, in speculative works, as many weeks are scarcely allowed to pass.

The foregoing precautions being attended to, there can be no better mode adopted for priming, or laying on the first coat on stucco, than by linseed or nut oil, boiled with driers before mentioned — taking care, in all cases, not to lay on too much, so as to render the surface rough and irregular, and not more than the stucco will absorb. It should then be covered with three or four coats of white lead, prepared as described for painting or wainscoting, allowing each coat sufficient time to dry hard. If time will permit, two or three days between each layer will be advantageous. When the stucco is intended to be finished in any given tint, as gray, light green, &c., it will then be proper, about the third coat of painting, to prepare the ground for such a tint, by a slight advance towards it. Gray is made with white lead, Prussian blue, ivory black, and lake; sage green, pea, and sea greens, with white, Prussian blue, and fine yellows; apricot and peach, with lake, white, and Chinese vermilion; fine yellow fawn color, with burnt *terra sienna*, or umber and white; and olive greens, with fine Prussian blues, and Oxfordshire ochre.

Distemper, or painting in water colors mixed with size stucco or plaster, which is intended to be painted in oil when finished, but not being sufficiently dry to receive the oil, may have a coating in water colors, of any given tint required, in order to give a more finished appearance to that part of the building. Straw colors may be made with French whites and ceruse, or white lead and masticot, or Dutch pink. Grays, full, with some whites and refiners' verditer. An inferior gray may be made with blue-black, or bone black, and indigo. Pea greens, with French green, Olympian green, &c. Fawn color, with burnt *terra de sienna*, or burnt umber and white, and so of any intermediate tint. The colors should all be ground very fine, and mixed with whiting and a size made with parchment, or some similar substance. Less than two coats will not be sufficient to cover the plaster and bear out with a uniform appearance. It must be recollected, that when the stucco is sufficiently dry, and it is desirable to have it painted in oil, the whole of the water colors ought to be removed, which may be easily done by washing, and, when quite dry, proceed with it after the direction given on oil painting in stucco.

If oil plastering has become disfigured by stains, or other blemishes, and if it be desired to have it painted in distemper, it is, in this case, advisable to give the old plastering, when properly cleaned off and prepared, one coat, at least, of white lead ground in oil, and used with spirits of turpentine, which will generally fix old stains; and, when quite dry, take water colors very readily.

TABLES

Showing the Weight of different Materials, Strength of Columns, &c., &c.

OF THE COHESIVE FORCE OF METALS AND WOODS.

Weight or Force necessary to tear asunder one Square Inch, in Avoirdupois Pounds.

METALS.

	lbs.		lbs.
Copper, cast	22·500	Iron, wire	85·700–113·
" wire	61·200	" medium bar	60·000
Iron, cast; gray, 2 fusion	30·680	" inferior bar	30·000
" " English	52·000	Lead, cast	·880
" " French	70·000	" milled	3·320
" " " soft	63·600	Silver wire	38·257
" " German	68·300	Steel, soft	120·000
Iron, wrought	60·000	" fine	135·000
" " Swedish	72·000	" razor, tempered	150·000
" " German	69·000		

WOODS.

	lbs.		lbs.
Ash, white, seasoned	14·000	Mahogany	21·800
" red, seasoned	17·800	" Spanish	12·000
Birch	15·000	Maple	10·500
Bay	14·500	Oak, American, white	11·500
Beech	11·500	" English	10·000
Box	20·000	" seasoned	13·600
Cedar	11·400	Pine, pitch	12·000
Chestnut, sweet	10·500	" Norway	13·000
Elm	13·400	Sycamore	13·000
Fir, strongest	12·000	Walnut	17·800
" American	8·800	Willow	13·000
Locust	20·500		

ON THE RESISTANCE TO CRUSHING WOOD.

According to the experiments of Rondelet, made on a hydrostatic press, on cubes of an inch in length, it required from 5000 to 6000 pounds per square inch to crush *oak;* and under this pressure its length was diminished more than one third. To crush *fir*, it required from 6000 to 7000 pounds per square inch; and the length was reduced one half. Mr. Rennes's trials, which are considered the most precise on this subject, afforded results considerably lower than those of Rondelet. The following are the results of his experiments:—

Base 1 inch square, height 1 inch,	Elm was crushed by		1,284 lbs.
" " " " "	White deal	"	1,928 "
" " " " "	American pine	"	1,606 "
" " " " "	English oak	"	3,860 "
" " " " "	African teak	"	8,480 "
" " " length 4 inches,	" "	"	5,147 "
" 3 inches square, length 6 to 9,	" oak	"	60,480 "

The load a piece of timber will bear, when pressed in the direction of its length, without risk of being crushed, may be found by the following rule, when the pressure is exactly in the axis of the piece:—

Rule.—Multiply the area of the piece in inches by the weight that has been found capable of crushing a square inch of the same kind of wood. (See the preceding experiments.) Then *one fourth* of the product will give the greatest load in pounds that the piece would bear with safety.

TO SHOW THE WEIGHT OR PRESSURE

A Column of Cast Iron will sustain with Safety.

Length or Height in feet.	8	10	12	14	16	18	20	22	24
Diameter.	Weight in cwts.	Weight in cwts.	Weight in cwts.	Weight in cwts.	Weight in cwts.	Weight in cwts.	Weight in cwts.	Weight in cwts.	Weight in cwts.
2½ in.	91	77	65	55	47	40	34	29	25
3 "	145	128	111	97	84	73	64	56	49
3½ "	214	191	172	156	135	119	106	94	83
4 "	288	266	242	220	198	178	160	144	130
4½ "	379	354	327	301	275	251	229	208	189
5 "	479	452	427	394	365	337	310	285	262
6 "	573	550	525	497	469	440	413	386	360
7 "	989	959	924	887	848	808	765	725	686
8 "	1289	1259	1224	1185	1142	1097	1052	1005	959
9 "	1672	1640	1603	1561	1515	1467	1416	1364	1311
10 "	2077	2045	2007	1964	1916	1865	1811	1755	1697
11 "	2520	2490	2450	2410	2358	2305	2248	2189	2127
12 "	3020	2970	2930	2900	2830	2780	2730	2670	2600

SHOWING THE WEIGHT

Of solid Cylinders of Cast Iron, twelve Inches long, in Avoirdupois Pounds.

Inches diam.	Weight in lbs.	Inches diam.	Weight in lbs.	Inches diam.	Weight in lbs.	Inches diam.	Weight in lbs.
¾	1·394	2½	15·492	4½	50·193	8	158·638
⅞	1·897	2⅝	17·080	4¾	55·926	8½	179·087
1	2·478	2¾	18·745	5	61·968	9	200·774
1⅛	3·137	2⅞	20·488	5¼	68·319	9½	223·704
1¼	3·873	3	22·308	5½	74·981	10	247·872
1⅜	4·686	3⅛	24·206	5¾	81·925	10½	273·278
1½	5·577	3¼	26·181	6	89·234	11	299·925
1⅝	6·545	3⅜	28·234	6¼	96·825	11½	327·811
1¾	7·591	3½	30·364	6½	104·726	12	356·935
1⅞	8·714	3⅝	32·572	6¾	112·936	13	418·903
2	9·915	3¾	34·857	7	121·457	14	485·830
2⅛	11·193	3⅞	37·219	7¼	130·287	15	557·712
2¼	12·548	4	39·660	7½	139·428	16	634·552
2⅜	13·981	4¼	44·771	7¾	148·878		

NOTE.—Cubic inches of cast iron × ·263 = lbs. avoirdupois. Circular inches of cast iron × ·2065 = lbs. avoirdupois.

WEIGHT OF CAST-METAL CYLINDERS.

The cylinders are solid, each one foot in length.

Diameter.	Iron Cylinders.	Copper Cylinders.	Brass Cylinders.	Lead Cylinders.
inch.	lbs.	lbs.	lbs.	lbs.
1	2·5	3·0	2·9	3·9
2	9·8	12·0	11·4	15·5
3	22·1	27·0	25·8	34·8
4	39·3	47·9	45·8	61·9
5	61·4	74·9	71·6	96·7
6	88·4	107·8	103·0	139·3
7	120·3	146·8	140·2	189·6
8	157·1	191·7	183·2	247·7
9	198·8	242·7	231·8	313·4
10	245·4	299·5	286·2	387·0

WEIGHT OF CAST-IRON PIPES.

This table shows the weight of pipes one foot long, of bores from 1 inch to 12 inches in diameter, advancing by one fourth of an inch; and of thicknesses from one fourth of an inch to one and one fourth inch, advancing by one eighth of an inch.

Bore.	¼	⅜	½	⅝	¾	⅞	1	1⅛	1¼
inch.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
1	3·1	5·1	7·4	10·0	12·9	16·1	19·6	23·5	27·6
1¼	3·7	6·0	8·6	11·5	14·7	18·3	22·1	26·2	30·7
1½	4·3	6·9	9·8	13·0	16·6	20·4	24·5	29·0	33·7
1¾	4·9	7·8	11·1	14·6	18·4	22·6	27·0	31·8	36·8
2	5·5	8·8	12·3	16·1	20·3	24·7	29·5	34·5	39·9
2¼	6·1	9·7	13·5	17·6	22·1	26·8	31·9	37·3	43·0
2½	6·7	10·6	14·7	19·2	23·9	28·9	34·4	40·0	46·0
2¾	7·4	11·5	16·0	20·7	25·7	31·1	36·8	42·8	49·1
3	8·0	12·4	17·2	22·2	27·6	33·3	39·3	45·6	52·2
3¼	8·6	12·3	18·4	23·8	29·5	35·4	41·7	48·3	55·2
3½	9·2	14·2	19·6	25·3	31·3	37·6	44·2	51·1	58·3
3¾	9·8	15·2	20·9	26·9	33·1	39·7	46·6	53·8	61·4
4	10·4	16·1	22·1	28·4	35·0	41·9	49·1	56·6	64·4
4¼	11·1	17·1	23·4	30·0	36·9	44·1	51·6	59·4	67·6
4½	11·7	18·0	24·5	31·4	38·7	46·2	54·0	62·1	70·6
4¾	12·3	18·9	25·8	33·0	40·5	48·3	56·5	64·9	73·6
5	12·9	19·8	27·0	34·5	42·3	50·5	58·9	67·6	76·7
5¼	13·5	20·7	28·2	36·1	44·2	52·6	61·4	70·4	79·8
5½	14·1	21·6	29·5	37·6	46·0	54·8	63·8	73·2	82·8
5¾	14·7	22·6	30·7	39·1	47·9	56·9	66·3	76·0	85·9
6	15·3	23·5	31·9	40·7	49·7	59·1	68·7	78·7	88·8
6¼	16·0	24·4	33·1	42·2	51·5	61·2	71·2	81·2	92·0
6½	16·6	25·3	34·4	43·7	53·4	63·4	73·4	84.2	95·1
6¾	17·2	26·2	35·6	45·3	55·2	65·3	76·1	87·0	98·2
7	17·8	27·2	36·8	46·8	56·8	67·7	78·5	89·7	101·2
7¼	18·4	28·1	38·1	48·1	58·9	69·8	81·0	92·5	104·2
7½	19·0	29·0	39·1	49·9	60·7	72·0	83·5	95·3	107·4
7¾	19·6	29·7	40·5	51·4	62·6	74·1	85·9	98·0	110·5
8	20·0	30·8	41·7	52·9	64·4	76·2	88·4	100·8	113·5
8¼	20·9	31·7	43·0	54·5	66·3	78·4	90·8	103·5	116·6
8½	21·7	32·9	44·4	56·2	68·3	80·8	93·5	106·5	119·9
8¾	22·1	33·6	45·4	57·5	70·0	82·7	95·7	109·1	122·7
9	22·7	34·5	46·6	59·1	71·8	84·8	98·2	111·8	125·8
9¼	23·3	35·4	47·9	60·6	73·6	87·0	100·6	114·6	128·9
9½	23·9	36·4	49·1	62·1	75·5	89·1	103·1	117·4	131·9
9¾	24·6	37·3	50·3	63·7	77·3	91·3	105·5	120·1	135·0
10	25·2	38·2	51·5	65·2	79·2	93·4	108·0	122·8	138·1
10¼	25·8	39·1	52·8	66·7	81·0	95·6	110·4	125·6	141·1
10½	26·4	40·0	54·0	68·3	82·8	97·7	112·9	128·4	144·2
10¾	27·0	41·0	55·2	69·8	84·7	99·9	115·4	131·2	147·3
11	27·6	41·9	56·5	71·3	86·5	102·0	117·8	133·9	150·3
11¼	28·2	42·8	57·7	72·9	88·4	104·2	120·3	136·7	153·4
11½	28·8	43·7	58·9	74·4	90·2	106·3	122·7	139·4	156·4
11¾	29·5	44·6	60·1	75·9	92·0	108·5	125·2	142·2	159·5
12	30·1	45·6	61·4	77·5	93·6	110·6	127·6	145·0	162·6

WEIGHT OF METAL PLATES.

This table shows the weight of a square foot of different meta plates, of thicknesses from one sixteenth of an inch to one inch, advancing by a sixteenth.

Inch.	Wrought Iron.	Cast Iron.	Cast Copper.	Cast Brass.	Cast Lead.	Cast Zinc.	Cast Tin.	Cast Silver.
16ths.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
1	2·5	2·3	2·9	2·7	3·7	2·3	2·4	3·4
2	5·1	4·7	5·7	5·5	7·4	4·7	4·7	6·8
3	7·6	7·0	8·6	8·2	11·1	7·0	7·1	10·2
4	10·1	9·4	11·4	11·0	14·8	9·4	9·5	13·6
5	12·7	11·7	14·3	13·7	18·5	11·7	11·9	17·0
6	15·2	14·0	17·2	16·4	22·2	14·0	14·2	20·5
7	17·9	16·4	20·0	19·2	25·9	16·4	16·6	23·9
8	20·3	18·8	22·9	21·9	29·5	18·7	19·0	27·3
9	22·8	21·1	25·7	24·6	33·2	21·1	21·4	30·7
10	25·4	23·5	28·6	27·4	36·9	23·4	23·7	34·1
11	27·9	25·8	31·4	30·1	40·6	25·7	26·1	37·5
12	30·4	28·1	34·3	32·9	44·3	28·1	28·5	40·9
13	32·9	30·5	37·2	35·6	48·0	30·4	30·9	44·3
14	35·5	32·9	40·0	38·3	51·7	32·8	33·2	47·7
15	38·0	35·2	42·9	41·2	55·4	35·1	35·6	51·1
16	40·6	37·6	45·8	43·9	59·1	37·5	38·0	54·6

THE WEIGHT, IN POUNDS, OF A FOOT IN LENGTH OF CAST IRON

Side of the square or diameter	Square.	Hexagon	Octagon.	Circle.	Side of the square or diameter	Square.	Hexagon	Octagon.	Circle.
inch.					inch.				
½	·781	·675	·650	·612	6½	132·031	114·271	109·948	103·696
¾	1·756	1·528	1·471	1·387	6¾	142·381	123.231	118·534	111·825
1	3·125	2·703	2·693	2·451	7	153·125	132·528	127·478	120·372
1¼	4·881	4·225	4·065	3·851	7¼	161·256	142·162	136·743	128·986
1½	7·031	6·085	5·856	5·521	7½	175·781	152·037	146·337	138·056
1¾	9·568	8·281	7·971	7·515	7¾	187·693	162·449	156·259	147·415
2	12·520	10·815	10 412	9·815	8	200·000	173·099	166 503	157·078
2¼	15·818	13·990	13·168	12·425	8¼	212·693	184·087	177·071	167·049
2½	19·531	16·900	16·256	15·337	8½	225·781	195·412	187·365	177·328
2¾	23·631	20·450	19·671	18·559	8¾	239·256	207·078	199·127	187·912
3	28·125	24·340	23·412	22·087	9	253·125	219·078	210·721	199·203
3¼	33·009	28·565	27·475	25·921	9¼	266·781	231·418	222·600	210·800
3½	38·281	33·131	31·818	30·065	9½	282·031	244·100	234·793	221·506
3¾	43·943	38·031	36·581	31·512	9¾	296·968	257·105	247·315	233·318
4	50·000	43·271	41·621	39·268	10	312·500	270·471	260·163	245·437
4¼	56·443	48·353	46·990	44·331	10¼	328 318	284·159	273·341	257·859
4½	63·281	54·768	52·681	49·700	10½	344·531	298·193	286·828	270·593
4¾	70·506	61·021	58·696	55·375	10¾	351·131	312·559	300·646	283·633
5	78·125	67·515	65·040	61·359	11	378·125	327·268	314·796	296·978
5¼	86·131	74·549	71·701	67·709	11¼	393·216	342·315	329·268	310·631
5½	94·531	81·815	78·696	74·243	11½	410·281	357·693	344·062	324·587
5¾	103·318	89·421	86·015	81·126	11¾	429·023	373·325	359·187	338·856
6	112·500	97·368	93·656	88·354	12	450·000	389·475	374·631	353·428
6¼	122·058	105·640	101·621	95·871					

OF THE WEIGHT OF A CUBIC FOOT OF VARIOUS SUBSTANCES,

In common Use for Building.

	lbs.
Sand, solid	112·5
Sand, loose	95
Earth	93·75
Common Soil	124
Strong Soil	127
Clay	120 to 135
Clay and Stone	158
Brick	119
Granite	169
Marble	166 to 169
Sand, one cubic yard	3037
Common Soil, one cubic yard	3429

THE NUMBER OF NAILS AND SPIKES TO THE POUND,

Of various Sizes, as manufactured at the Troy Iron and Nail Factory, N. Y.

Size of Nails.	Number to the lb.	Boat Spikes.	Diam. of Rod.	No. Spikes to the lb.	Ship Spikes.	Diam. of Rod.	No. Spikes to the lb.
3 penny	600	No. 4	¼	13	No. 4	5/16	8
4 "	360	" 5	5/16	8	" 5	⅜	6
6 "	200	" 6	⅜	5	" 6	⅜	5
8 "	110	" 7	⅜	4	" 7	⅜	3½
10 "	88				" 8	⅜	3
12 "	68				" 9	9/16	2
20 "	40				" 10	9/16	1½

FOR FINDING THE STRAIN THAT MAY BE APPLIED TO A HEMPEN ROPE WITH SAFETY.

Circumference.	Pounds.	Circumference.	Pounds.	Circumference.	Pounds.	Circumference.	Pounds.
1·00	200·0	3·00	1800·0	4·75	4512·5	6·50	8450·0
1·25	312·5	3·25	2112·5	5·00	5000·0	6·75	9112·5
1·50	450·0	3·50	2450·0	5·25	5512·5	7·00	9800·0
1·75	612·5	3·75	2812·5	5·50	6050·0	7·25	10512·5
2·00	800·0	4·00	3200·0	5·75	6612·5	7·50	11250·0
2·25	1012·5	4·25	3612·5	6·00	7200·0	7·75	12012·5
2·50	1250·0	4·50	4050·0	6·25	7812·5	8·00	12800·0
2·75	1512·5						

WEIGHTS OF COPPER AND SPIKES

Size.	Weight of Cop'r Bolts per foot.	Number of Composition Spikes to the 100 lbs.	Weight of Sheathing Copper, and Yellow Sheathing Metal, per sheet.					
			Size.	Weight.		Size.	Weight.	
	lbs.		ounces.	lbs.	ozs.	ounces.	lbs.	ozs.
		5 in. round head, 500						
½	·7567	5 " square " 434	14	4	1	24	7	0
⅝	1·1824	5½ " " " 400	16	4	10	26	7	9
¾	1·7027	6 " " " 377	18	5	4	28	8	3
⅞	2·3176	6½ " " " 295	20	5	13	30	8	12
1	3·0270	7 " " " 275	22	6	7	32	9	5
1⅛	3·8312	7½ " " " 210						
1¼	4·9298	8 " " " 200						
		8½ " " " 148						

SHOWING THE CONTENTS OF BRICK WALLS, NO. OF BRICKS, &c.

This table is calculated in round numbers, and is not far from the average of walls made of the Charlestown, Fresh Pond, or eastern bricks — the latter being about two thirds the size of the two former.

Number of Bricks.	Width of Bricks to a superficial foot.	Thickness of Wall, in inches.	No. of Bricks to a superficial foot.	Contents of Wall, in superficial feet.
1000	1	4	7	143
"	2	8	14	71
"	3	12	21	47½
"	4	16	28	35½
"	5	20	35	28¾
"	6	24	42	23¾
"	7	28	49	20½
"	8	32	56	17¾
"	9	36	63	15¾

1 cask of lime will plaster about 50 yards.
1 cask will skim about 200 yards.
4 casks will ordinarily employ 45 bushels of sand.
1 cask will ordinarily employ 5 pecks of hair.
60 yards of plastering will cover 1000 laths.
100 pounds of threepenny nails will lay 900 yards.

WEIGHT OF LEAD PIPES, TWELVE INCHES LONG.

⅛ in. thick, from 1 to 3 inches bore.						¼ in. thick, from 1 to 3 inches bore.					
Size.	Weight	Size.	Weight	Size.	Weight	Size.	Weight	Size.	Weight	Size.	Weight.
1	2·19	1¾	3·64	2½	5·09	1	4·85	1¾	7·76	2½	10·66
1⅛	2·43	1⅞	3·83	2⅝	5·33	1⅛	5·34	1⅞	8·17	2⅝	11·15
1¼	2·66	2	4·12	2¾	5·57	1¼	5·81	2	8·73	2¾	11·63
1⅜	2·91	2⅛	4·29	2⅞	5·82	1⅜	6·3	2⅛	9·21	2⅞	12·12
1½	3·15	2¼	4·61	3	6·06	1½	6·79	2¼	9·7	3	12·61
1⅝	3·39	2⅜	4·92			1⅝	7·27	2⅜	10·25		

OF CYLINDRICAL MEASURES,

Designed for the computation of the contents of lead pipes, from 1 inch diameter to 3 and upwards; also, cisterns of 10 feet diameter and under; and the quantity and weight of water in pumps, suction pipes, &c., of 1 inch diameter and upwards.

Estimated at one foot deep.

Inches diameter.	Cubic feet and decimal parts.	Ale gallons and parts.	Wine gallons and parts.	Weight of water in lbs. and parts.	Dry bushels and parts.
1	·0055	·033	·04	·34	·0044
2	·0218	·134	·16	1·36	·0175
3	·0491	·301	·37	3·06	·0394
4	·0873	·534	·65	5·45	·0700
5	·136	·835	1·02	8·52	·110
6	·196	1·20	1·47	12·27	·158
7	·267	1·64	2·00	16·70	·215
8	·349	2·14	2·61	21·82	·281
9	·442	2·71	3·30	27·61	·355
10	·545	3·34	4·08	34·09	·438
11	·660	4·04	4·94	41·25	·530
12	·785	4·81	5·88	49·09	·631
24	3·14	19·25	23·52	196·36	2·521
36	7·07	43·30	52·92	441·79	5·68
48	12·57	77·00	94·08	785·44	10·10
50	13·64	83·55	102·00	852·21	11·00
60	19·64	120·30	146·88	1227·19	15·78
72	28·28	173·20	211·51	1767·15	22·72
84	38·49	235·81	287·88	2405·28	30·92
96	50·27	308·00	376·01	3141·59	40·39
108	63·62	389·79	475·89	3976·08	51·12
120	78·54	481·25	587·52	4903·74	63·11

N. B. If the diameter should fall between any of the numbers in the first column, the mean proportional contents may be found by adding the two contents between which it falls, and dividing by 2. Suppose it falls between 108 and 120 of the diameters, required the wine gallons in 114 inches, or 9 feet 6 inches diameter,

which falls between	587·52
and	475·89
	2) 1063·41
Answer,	531·70½

Or, if between 60 and 72, say 64 inches, or 5 feet 4 inches; one third of 12 is 4; then required the cubic feet and parts.

	28·28
Subtract	19·64
Divide	3) 8·64
	2·88
Add	19·64
Answer,	22·52

Any depth may be found, by multiplying by the depth any of the numbers in the contents; as, required the number of ale gallons in 24 inches diameter, at 6 feet deep.

	19·25
	6
Answer,	115·50

GLOSSARY

OF

ARCHITECTURAL TERMS.

Abacus. The upper member of the capital of a column whereon the architrave rests. Scammozzi uses this term for a concave moulding in the capital of the Tuscan pedestal, which, considering its etymology, is an error.

Abutment. The solid part of a pier, from which an arch springs.

Acanthus. A plant called in English *bear's breech*, whose leaves are employed for decorating the Corinthian and Composite capitals. The leaves of the acanthus are used on the bell of the capital, and distinguish the two rich orders from the three others.

Accompaniments. Buildings or ornaments having a necessary connection or dependence, and which serve to make a design more or less complete — a characteristic peculiarity of ornaments.

Accouplement. Among carpenters, a tie or brace; sometimes the entire work, when framed.

Acroteria. The small pedestals placed on the extremities and apex of a pediment.

Admeasurement. Adjustment of proportions; technically, an estimate of the quantity of materials and labor of any kind used in a building.

Alcove. The original and strict meaning of this word, which is derived from the Spanish *alcoba*, is that part of a bed-chamber in which the bed stands, and is separated from the other parts of the room by columns or pilasters.

Amphiprostyle. In ancient architecture, a temple with columns in the rear, as well as in the front.

Amphitheatre. A double theatre, of an elliptical form, on the ground plan, for the exhibition of the ancient gladiatorial fights and other shows.

Ancones. The consoles or ornaments cut on the keys of arches, sometimes serving to support busts or other figures.

Annulet. A small, square moulding, which crowns or accompanies a larger. Also, that fillet which separates the flutings of a column. It is sometimes called a *list*, or *listella*, which see.

Antæ. A name given to pilasters attached to a wall.

Apophyge. That part of a column between the upper fillet of the base and the cylindrical part of the shaft of the column, which is usually curved into it by a cavetto.

Aræostyle. That style of building in which the columns are distant four, and sometimes five, diameters from each other; but the former is the proportion to which the term is usually applied. This columnar arrangement is suited to the Tuscan order only.

Arcade. A series of arches, of apertures, or recesses, a continued covered vault, or arches supported on piers or columns instead of galleries. In Italian towns, the streets are lined with arcades like those of Covent Garden and the Royal Exchange.

Arch. An artful arrangement of bricks, stones, or other materials, in a curvilinear form, which, by their mutual pressure and support, perform the office of a lintel, and carry superincumbent weights — the whole resting at its extremities upon piers or abutments.

Arch Buttress, or Flying Buttress, (in Gothic architecture,) an arch springing from a buttress or pier, and abutting against a wall.

Archeion. The most retired and secret place in Grecian temples, used as a treasury, wherein were deposited the richest treasures pertaining to the deity to whom the temple was dedicated.

Architect. One who designs and superintends the erection of buildings.

Architrave. The lower of the primary divisions of the entablature. It is placed immediately upon the abacus of the capital.

Astragal. From the Greek word for a bone in the foot, to which this moulding was supposed to bear a resemblance. A small moulding, whose profile is semicircular, and which bears also the name of *talon*, or *tondino*. The astragal is often cut into beads and berries, and used in ornamental entablatures to separate the faces of the architrave.

Attic. A term that expresses any thing invented or much used in Attica, or the city of Athens. A low story erected over an order of architecture, to finish the upper part of the building, being chiefly used to conceal the roof, and give greater dignity to the design.

Attic Base. See *Base*.

Attic Order. An order of low pilasters, generally placed over some other order of columns. It is improperly so called, for the arrangement can scarcely be called an order.

Auriel, or Oriel, (in Gothic architecture,) a window projecting outwards for private conference; whence its appellation.

Balcony. A projection from the surface of a wall, supported by consoles or pillars, and surrounded by a balustrade.

Baluster. A small pillar or pilaster, serving to support a rail. Its form is of considerable variety, in different examples. Sometimes it is round; at other times square: it is adorned with mouldings and other decorations, according to the richness of the order it accompanies.

Balustrade. A connected range of a number of balusters on balconies, terraces around altars, &c. See *Baluster*.

Band. A term used to express what is generally called a *face* or *facia*. It more properly means a flat, low, *square, profiled* member, without respect to its place. That from which the Corinthian or other modillions or the dentils project is called the modillion band, or the dentil band, as the case may be.

Bandelet. A diminutive of the foregoing term, used to express any narrow, flat moulding. The tænia on the Doric architrave is called its *bandelet*.

Banker. A stone bench, on which masons cut and square their work.

Banquet. The footway of a bridge raised above the carriage-way.

Barrel Drain. A drain of the form of a hollow cylinder.

Base. The lower part of a column, moulded or plain, on which the shaft is placed.

Basement. The lower part or story of a building, on which an order is placed, with a base or plinth, die, and cornice.

Basil. A word used by carpenters, &c., to denote the angle to which any edge tool is ground and fitted for cutting wood, &c.

Basin, en Coquille, that is, shaped like a shell.

Basin is likewise used for a dock.

Basket. A kind of vase in the form of a basket, filled with flowers or fruits, serving to terminate some decoration.

Basilica. A town or court hall, a cathedral, a palace, where kings administer justice.

Basso Rilievo, or Bas Relief. The representation of figures projecting from a background, without being detached from it. Though this word, in general language, implies all kinds of rilievoes, from that of coins to more than one half of the thickness from the background.

Bath. A receptacle of water, appropriated for the purpose of bathing.

Batten. A scantling of stuff from two to six inches broad, and from ⅝ to two inches thick, used in the boarding of floors; also upon walls, in order to secure the lath on which the plaster is laid.

Batter. When a wall is built in a direction that is not perpendicular.

Battlements. Indentations on the top of a parapet, or wall, first used in ancient fortifications, and afterwards applied to churches and other buildings.

Bay, (in Gothic architecture,) an opening between piers, beams, or mullions.

Bay Window. See *Auriel.*

Bead and Flush Work. A piece of panel work, with a bead run on each edge of the included panel.

Bead and But Work. A piece of framing in which the panels are flush, having beads stuck or run upon the two edges with the grain of the wood in their direction.

Bed Mouldings. Those mouldings in all the orders between the corona and frieze.

Billet Moulding, (in Gothic architecture,) a cylindrical moulding, discontinued and renewed at regular intervals.

Boltel, (in Gothic architecture,) slender shafts, whether arranged round a pier, or attached to doors, windows, &c. The term is also used for any cylindrical moulding.

Boss, (in Gothic architecture,) a sculptured protuberance at the interjunction of the ribs in a vaulted roof.

Bossage. (A French term.) Any projection left rough on the face of a stone for the purpose of sculpture, which is usually the last thing finished.

Boultin. A name given to the moulding, called the egg or quarter round.

Broach, (in Gothic architecture,) a spire, or polygonal pyramid, whether of stone or timber.

Bracket, (in Gothic architecture,) a projection to sustain a statue, or other ornament, and sometimes supporting the ribs of a roof.

Bulk. A piece of timber from four to ten inches square, and is sometimes called ranging timber.

Buttress, (in Gothic architecture,) a projection on the exterior of a wall, to strengthen the piers and resist the pressure of the arches within.

Cabling. The filling up of the lower part of the fluting of a column with a solid cylindrical piece. Flutings thus treated are said to be cabled.

Caisson. A name given to the sunk panels of various geometrical forms, symmetrically disposed in flat or vaulted ceilings, or in soffits, generally.

Canopy, (in Gothic architecture,) the ornamented dripstone of an arch. It is usually of the ogee form.

Canted, (in Gothic architecture,) any part of a building having its angles cut off is said to be canted.

Capital. The head or uppermost part of a column or pilaster.

Carpenter. An artificer whose business is to cut, fashion, and join timbers together, and other wood, for the purpose of building: the word is from the French *charpentier*, derived from *charpentie*, which signifies timber.

Carpentry, or that branch which is to claim our attention, is divided into three principal heads, viz., Constructive, Descriptive, and Mechanical; of these, Descriptive carpentry shows the lines or methods for forming every species of work in *plano*, by the rules of geometry; Constructive carpentry, the practice of reducing the wood into particular forms, and joining the forms so produced, so as to make a complete whole, according to the intention of the design; and Mechanical carpentry displays the relative strength of the timbers, and the strains to which they are subjected by their disposition.

Cartouch. The same as modillions, except that it is exclusively used to signify those blocks or modillions at the eaves of a house. See *Modillion.*

Caryatides. Figures of women, which serve instead of columns to support the entablature.

Casement. The same as Scotia, which see. The term is also used for a sash hung upon hinges.

Caulicules. The volute or twist under the flower, in the Corinthian capital.

Cavetto. A hollow moulding, whose profile is a quadrant of a circle, principally used in cornices.

Cell. See *Naos.*

Cincture. A ring, list, or fillet, at the top or bottom of a column, serving to divide the shaft of the column from its capital and base.

Chamfer, (in Gothic architecture,) an arch, or jamb of a door, canted.

Champ, (in Gothic architecture,) a flat surface in a wall or pier, as distinguished from a moulding, shaft, or panel.

Cinquefoil, (in Gothic architecture,) an ornamental figure, with five leaves or points.

Column. A member in architecture of a cylindrical form, consisting of a base, a shaft or body, and a capital. It differs from the pilaster, which is square on the plan. Columns should always stand perpendicularly.

Composite Order. One of the orders of architecture.

Cope, Coping, (in Gothic architecture,) the stone covering the top of a wall or parapet.

Corbel, (in Gothic architecture,) a kind of bracket. The term is generally used for a continued series of brackets on the exterior of a building supporting a projecting battlement, which is called a *corbel table.*

Corinthian Order. One of the orders of architecture.

Cornice. The projection, consisting of several members, which crowns or finishes an entablature, or the body or part to which it is annexed. The cornice used on a pedestal is called the cap of the pedestal.

Corona, is that flat, square, and massy member of a cornice, more usually called the drip or larmier, whose situation is between the cimatium above and the bed moulding below. Its use is to carry the water, drop by drop, from the building.

CORRIDOR. A gallery or open communication to the different apartments of a house.

CORSA. The name given by Vitruvius to a platband or square facia, whose height is more than its projecture.

CRENELLE, (in Gothic architecture,) the opening of an embattled parapet.

CREST, (in Gothic architecture,) a crowning ornament of leaves running on the top of a screen or other ornamental work.

CROCKET, (in Gothic architecture,) an ornament of leaves, running up the sides of a gable, or ornamented canopy.

CUPOLA. A small room, either circular or polygonal, standing on the top of a dome. By some it is called a lantern.

CUSHIONED. See *Frieze.*

CUSP, (in Gothic architecture,) a name for the segments of circles forming the trefoil, quatrefoil, &c.

CYMA, called also *Cymatium*, its name arising from its resemblance to a wave. A moulding which is hollow in its upper part, and swelling below.

DECAGON. A plain figure, having ten sides and angles.

DECASTYLE. A building having ten columns in front.

DECEMPEDA. (*Decem*, ten, and *pes*, foot, Lat.) A rod of ten feet, used by the ancients in measuring. It was subdivided into twelve inches in each foot, and ten digits in each inch; like surveyors' rods used in measuring short distances, &c.

DECIMAL SCALE. Scales of this kind are used by draughtsmen, to regulate the dimensions of their drawings.

DECORATION. Any thing that enriches or gives beauty and ornament to the orders of architecture.

DEMI METOPE. The half a metope, which is found at the retiring or projecting angles of a Doric frieze.

DENTILS. Small, square blocks or projections used in the bed mouldings of the cornices in the Ionic, Corinthian, Composite, and sometimes Doric orders.

DETAILS OF AN EDIFICE. Drawings or delineations for the use of builders, otherwise called working plans.

DIAGONAL SCALE is a scale subdivided into smaller parts by secondary intersections or oblique lines.

DIAMETER. The line in a circle passing from the circumference through the centre.

DIAMOND. A sharp instrument formed of that precious stone, and used for cutting glass.

DIAPERED, (in Gothic architecture,) a panel, or other flat surface, sculptured with flowers, is said to be diapered.

DIASTYLE. That intercolumniation or space between columns, consisting of three diameters — some say four diameters.

DIE, or DYE. A naked, square cube. Thus the body of a pedestal, or that part between its base and cap, is called the die of the pedestal. Some call the abacus the die of the capital.

DIMENSION. (*Dimetier*, Lat.) In geometry, is either length, breadth, or thickness.

DIMINUTION. A term expressing the gradual decrease of thickness in the upper part of a column.

DIPTERAL. A term used by the ancients to express a temple with a double range of columns in each of its flanks.

DODECAGON. A regular polygon, with twelve equal sides and angles.

DODECASTYLE. A building having twelve columns in front.

DOME. An arched or vaulted roof, springing from a polygonal, circular, or elliptic plane.

DORIC ORDER. One of the five orders of architecture.

DORMANT, or DORMER WINDOW, (in Gothic architecture,) a window set upon the slope of a roof or spire.

DOOKS. Flat pieces of wood, of the shape and size of a brick, inserted in brick walls, sometimes called plugs or wooden bricks.

DOOR. The gate or entrance of a house, or other building, or of an apartment in a house.

DORMITORY. A sleeping-room.

DRAWING, or WITHDRAWING-ROOM. A large and elegant apartment, into which the company withdraw after dinner.

DRESSING-ROOM. An apartment contiguous to the sleeping-room, for the convenience of dressing.

DRIP, in (Gothic architecture,) a moulding much resembling the cimatium of Roman architecture, and used for the same purpose as a canopy over the arch of a door or window.

DROPS. See *Guttæ.*

ECHINUS. The same as the ovolo or quarter round; but perhaps it is only called echinus with propriety.

EDGING. The reducing the edges of ribs or rafters, that they may range together.

ELBOWS OF A WINDOW. The two panelled flanks, one under each shutter.

ELEVATION. A geometrical projection drawn on a plane, perpendicular to the horizon.

EMBANKMENTS are artificial mounds of earth, stone, or other materials, made to confine rivers, canals, and reservoirs of water within their prescribed limits; also for levelling up of railroads, &c.

EMBRASURE, (in Gothic architecture,) the same as *Crenelle*, which see.

ENCARPUS. The festoons on a frieze, consisting of fruits, flowers, and leaves. See *Festoon.*

ENTABLATURE. The assemblage of parts supported by the column. It consists of three parts — the architrave, frieze, and cornice.

ENTAIL, (in Gothic architecture,) delicate carving.

ENTASIS. The slight curvature of the shafts of ancient Grecian columns, particularly the Doric, which is scarcely perceptible, and beautifully graceful.

ENTRESOL. See *Mezzanine.*

EPISTYLUM. The same as *Architrave*, which see.

EUSTYLE. That intercolumniation which, as its name would import, the ancients considered the most elegant, namely, two diameters and a quarter of a column. Vitruvius says this manner of arranging columns exceeds all others in strength, convenience, and beauty.

FACADE. The face or front of any considerable building to a street, court, garden, or other place.

FACIA. A flat member in the entablature or elsewhere, being in fact nothing more than a band or broad fillet.

FANE, PHANE, VANE, (in Gothic architecture,) a plate of metal usually cut into some fantastic form, and turning on a pivot, to determine the course of the wind.

FASTIGIUM. See *Pediment.*

FEATHER-EDGED BOARDS are narrow boards, made thin on one edge. They are used for the facings or boarding of wooden walls.

FESTOON. An ornament of carved work, representing a wreath or garland of flowers or leaves, or both, interwoven with each other.

FILLET. The small, square member which is placed above or below the various square or curved members in an order.

FINIAL, (in Gothic architecture,) the ornament, consisting usually of four crockets, which is employed to finish a pinnacle, gable, or canopy.

FLANK. The least side of a pavilion, by which it is joined to the main building.

FLATNING, in inside house painting, is the mode of finishing without leaving a gloss on the surface, which is done by adding the spirits of turpentine to unboiled linseed oil.

Fliers are steps in a series which are parallel to each other.
Flight of Stairs is a series of steps, from one landing-place to another.
Floors. The bottom of rooms.
Flutings. The vertical channels on the shafts of columns, which are usually rounded at the top and bottom.
Folding Doors are made to meet each other from opposite jambs, on which they are hung.
Foliage. An ornamental distribution of leaves or flowers on various parts of the building.
Foreshorten. A term applicable to the drawings or designs in which, from the obliquity of the view, the object is represented as receding from the opposite side of the plane of the projection.
Foundation. That part of a building or wall which is below the surface of the ground.
Foot. A measure of twelve inches, each inch being three barleycorns.
Frame. The name given to the wood work of windows enclosing glass, and the outward work of doors or windows, or window shutters, enclosing panels; and in carpentry, to the timber work supporting floors, roofs, ceilings, or to the intersecting pieces of timbers forming partitions.
Fret. A kind of ornamental work, which is laid on a plane surface. The Greek fret is formed by a series of right angles of fillets, of various forms and figures.
Frieze, or Frize. The middle member of the entablature of an order, which separates the architrave and the cornice.
Frontispiece. The face or fore front of a house; but it is a term more usually applied to its decorated entrance.
Front. A name given to the principal interior facade of a building.
Frustum. A piece cut off from a regular figure; the frustum of a cone is the part that remains when the top is cut off by an intersection parallel to its base, as the Grecian Doric column without a base.
Furrings are flat pieces of timber, plank, or board, used by carpenters to bring dislocated work to a regular surface.
Fust. The shaft of a column. See *Shaft*.

Gable, (in Gothic architecture,) the triangularly-headed wall which covers the end of a roof.
Gable Window, (in Gothic architecture,) a window in a gable. These are generally the largest windows in the composition, frequently occupying nearly the whole space of the wall.
Gablet, (in Gothic architecture,) a little gable. See *Canopy*.
Gage. In carpentry, an instrument to strike a line parallel to the straight side of any board or piece of stuff.
Gain. The bevelled shoulder of a binding joist.
Garland, (in Gothic architecture,) an ornamental band surrounding the top of a tower or spire.
Glyphs. The vertical channels sunk in the triglyphs of the Doric frieze.
Gola, or Gula. The same as *Ogee*, which see.
Gorge. The same as *Cavetto*, which see.
Gouge. A chisel of a semicircular form.
Granite. A genus of stone much used in building, composed chiefly of quartz, feldspar, and mica, forming rough and large masses of very great hardness.
Groin, (in Gothic architecture,) the diagonal line formed by the intersection of two vaults in a roof.
Groined Ceiling. A surface formed of three or more curved surfaces, so that every two may form a groin, all the groins terminating at one extremity in a common point.
Groove, or Mortise. The channel made by a joiner's plane in the edge of a moulding, style, or rail, to receive the tenon.
Ground Floor. The lowest story of a building.
Ground Plane. A line forming the ground of a design or picture, which line is a tangent to the surface of the face of the globe.
Ground Plot. The ground on which a building is placed.
Grounds. Joiners give this name to narrow strips of wood put in walls to receive the laths and plastering.
Guttæ, or Drops. Those frusta of cones in the Doric entablature which occur in the architrave below the tænia under each triglyph.
Gutters are a kind of canals in the roofs of houses, to receive and carry off rain water.

Halving. The junction of two pieces of timber, by inserting one into the other; in some cases, to be preferred to mortising.
Hand Railing. The art of forming hand rails round circular and elliptic well holes without the use of the cylinder.
Hanging Style of a Door is that to which the hinges are fixed.
Heel of a Rafter. The end or foot that rests upon the wall plate.
Helical Line of a Hand Rail. The line, or spiral line, representing the form of the hand rail before it is moulded.
Helix. The curling stalk under the flower in the Corinthian capital. See *Cauliculus*.
Hem. The spiral projecting part of the Ionic capital.
Hexastyle. A building having six columns in front.
Hood Mould, (in Gothic architecture.) See *Drip*.
Hook Pins. The same as *draw bore pins*, to keep the tenons in their place, while in the progress of framing; the pin has a head or notch in the outer end, to draw it at pleasure.
Hypæthral. Open at top; uncovered by a roof.
Hyperthyron. The lintel of a doorway.
Hypotrachelium. A term given by Vitruvius to the slenderest part of the shaft of a column, where it joins the capital. It signifies the part under the neck.

Ichnography. The transverse section of a building, which represents the circumference of the whole edifice; the different rooms and apartments, with the thickness of the walls; the dimensions and situation of the doors, windows, chimneys; the projection of columns, and every thing that could be seen in such a section, if really made in a building.
Impost. The layer of stone or wood that crowns a door post or pier, and which supports the base line of an arch or arcade; it generally projects, and is sometimes formed of an assemblage of mouldings.
Inch. The twelfth part of a foot. For the purpose of reckoning in decimal fractions, it is divided into ten parts or integers.
Inclined Plane. One of the mechanical powers used for raising ponderous bodies, in many instances, of immense weight; a declivity of a hill, &c.
Insular Column is a column standing by itself.
Insulated. Detached from another building.
Intaglio. Any thing with figures in relief on it.
Intercolumniation. The distance between two columns.
Intrados. The under-curved surface or soffit of an arch.
Inverted Arches. Such as have their intrados below the centre or axis.
Ionic Order. One of the orders of architecture.

Jack Plane. A plane about eighteen inches long, to prepare for the trying plane.
Jack Rafters. The jack timbers, which are fastened to the hip rafters and the wall plates.
Jambs. The side pieces of any opening in a wall, which bear the piece that discharges the superincumbent weight of such wall.
Joinery, in building, is confined to the nicer and more ornamental parts.

Jointer. A tool used for straightening and preparing stuff for joints, &c. This jointer is about two feet eight or ten inches long.

Kerf. The slit or cut in a piece of timber, or in a stone, by a saw.
King Post. The middle post in a section of rafters.

Label, (in Gothic architecture,) a name for the drip or hood moulding of an arch when it is returned square.

Lacunar, or Laquear. The same as *Soffit*.

Lantern, (in Gothic architecture,) a turret or tower placed above a building, pierced either with windows to admit light, or holes to let out steam.

Larmier. Called also *Corona*, which see.

Lath. A narrow slip of wood, $1\frac{1}{4}$ to $1\frac{1}{2}$ inches wide, $\frac{1}{4}$ to $\frac{3}{8}$ inch thick, and four feet long, used in plastering.

Leaves. Ornaments representing natural leaves. The ancients used two sorts of leaves, natural and imaginary. The natural were those of the laurel, palm, acanthus, and olive; but they took such liberties in the form of these, that they might almost be said to be imaginary, too.

Level. A surface which inclines to neither side.

Lining. Covering for the interior, as casing is covering for the exterior surface of a building.

Lintel. A piece of timber or stone, placed horizontally over a door, window, or other opening.

List, or Listel. The same as fillet or annulet.

Listing. The cutting the sapwood out from both edges of a board.

Loop, (in Gothic architecture,) a small, narrow window.

Louvre, (in Gothic architecture.) See *Lantern*.

Luffer Boarding. The same as blind slats.

Machicolations, (in Gothic architecture,) small openings in an embattled parapet, for the discharge of missile weapons upon the assailants. Frequently these openings are underneath the parapet; in which case, the whole is brought forward and supported by corbels.

Mechanical Carpentry. That branch of carpentry which teaches the disposition of the timbers according to their relative strength, and the strains to which they are subjected.

Mediæval Architecture. The architecture of England, France, Germany, &c., during the middle ages, including the Norman and early Gothic styles.

Members. (*Membrum*, Lat.) The different parts of a building; the different parts of an entablature; the different mouldings of a cornice, &c.

Metope. The square space between two triglyphs of the Doric order. It is sometimes left plain, at other times decorated with sculpture.

Mezzanine. A low story introduced between two principal stories.

Minerva Polias. A Grecian temple at Athens.

Minute. The sixtieth part of the diameter of a column. It is the subdivision by which architects measure the small parts of an order.

Mitre. An angle of forty-five degrees; a half of a right angle.

Modillion. An ornament in the entablature of richer orders, resembling a bracket.

Module. The semi-diameter of a column. This term is only properly used when speaking of the orders. As a semi-diameter, it consists of only thirty minutes. See *Minute*.

Mosaic. A kind of painting representing cubes of glass, &c., and is formed of different colored stones, for paving, &c. Specimens of this kind have been found among the ruins of antiquity.

Mouldings. Those parts of an order which are shaped into various curved or square forms.

Mouth. The same as *Cavetto*, which see.

Mutule. A projecting ornament of the Doric cornice, which occupies the place of the modillion, in imitation of the ends of rafters.

Mullion, (in Gothic architecture,) the framework of a window.

Naked. The unornamented, plain surface of a wall, column, or other part of a building.

Naos, or Cella. The part of a temple within the walls.

Newel. The solid, or imaginary solid, when the stairs are open in the centre, round which the steps are turned about.

Niche. A square or cylindrical cavity in a wall or other solid.

Obelisk. A tall, slender frustum of a pyramid, usually placed on a pedestal. The difference between an obelisk and a pyramid, independent of the former being only a portion of the latter, is, that it always has a small base in proportion to its height.

Octastyle. A building with eight columns in front.

Ogee, or Ogive. The same as *Cyma*, which see.

Order. An assemblage of parts, consisting of a base, shaft, capital, architrave, frieze, and cornice, whose several services, requiring some distinction in strength, have been contrived or designed in five several species — Tuscan, Doric, Ionic, Corinthian, and Composite; each of which has its ornaments, as well as general fabric, proportioned to its strength and character.

Ordonnance. The arrangement of a design, and the disposition of its several parts.

Orle. (*Ital.*) A fillet or band under the ovolo of the capital. Palladio applies the term also to the plinth of the base of a column or pedestal.

Ovolo. A moulding sometimes called a quarter round, from its profile, being the quadrant of a circle. When sculptured, it is called an echinus, which see.

Panel. A thin board, having all its edges inserted in the groove of a surrounding frame.

Parapet. From the Italian *Parapetto*, breast high. The defence round a terrace or roof of a building.

Parastatæ. Pilasters standing insulated.

Pavilion. A turret or small building generally insulated, and comprised beneath a single roof.

Pedestal. The substruction under a column or wall. A pedestal under a column consists of three parts — the base, the die, and the cornice or cap.

Pediment. The low, triangular, crowning ornament of the front of a building, or of a door, window, or niche.

Pend, (in Gothic architecture,) a vaulted roof without groining.

Pendant, (in Gothic architecture,) a hanging ornament in highly-enriched vaulted roofs.

Pinnacle, (in Gothic architecture,) a small spire.

Peripteral. A term used by the ancients to express a building encompassed by columns, forming, as it were, an aisle round the building.

Peristylium. In Greek and Roman houses, a court, square, or cloister.

Perspective is the science which teaches us to dispose the lines and shades of a picture, so as to represent, on a plane, the image of objects exactly as they appear in nature.

Piazza. A continued archway, or vaulting, supported by pillars or columns; a portico.

Pier. A solid between the doors or the windows of a building. The square or other formed mass or post to which a gate is hung.

Pilaster. A square pillar engaged in a wall.

Pile. A stake or beam of timbers, driven firmly into the ground.

Pillar. A column of irregular form, always disengaged, and always

deviating from the proportions of the orders; whence the distinction between a pillar and a column.

Platband. A square moulding, whose projection is less than its height or breadth.

Plinth. The square solid under the base of a column, pedestal, or wall.

Porch. An arched vestibule at the entrance of a church or other building.

Portico. A place for walking under shelter, raised with arches in the manner of a gallery; the portico is usually vaulted, but has sometimes a flat soffit or ceiling. This word is also used to denote the projection before a church or temple supported by columns.

Post. A piece of timber set erect in the earth. Perpendicular timbers of the wooden frame of a building.

Posticum. The back door of a temple; also the portico behind the temple.

Principal Rafters. The two inclined timbers which support the roof.

Profile. The contour of the different parts of an order.

Projecture. The prominence of the mouldings, and members beyond the naked surface of a column, wall, &c.

Proscenium. The front part of the stage of the ancient theatres, on which the actors performed.

Prostyle. A building or temple with columns in front only.

Purlins. Pieces of timber framed horizontally from the principal rafters, to keep the common rafters from sinking in the middle.

Pycnostyle. An intercolumniation equal to one diameter and a half.

Pyramid. A solid, with a square, polygonal, or triangular base, terminating in a point at top.

Quarter Round. See *Ovolo* and *Echinus*.

Quatrefoil, (in Gothic architecture,) an ornament in tracery, consisting of four segments of circles, or cusps, within a circle.

Quirk Mouldings. The convex part of Grecian mouldings, when they recede at the top, forming a reëntrant angle with the surface which covers the moulding.

Quoins. The external and internal angles of buildings, or of their members. The corners.

Radius, in geometry, is the semi-diameter of a circle, or a right line, drawn from the centre to the circumference; in mechanics, the spoke of a wheel.

Rails, in framing, the pieces that lie horizontal; and the perpendicular pieces are called styles, in wainscoting, &c.

Raking. A term applied to mouldings whose arrises are inclined to the horizon.

Resistance, in mechanics, that power which acts in opposition to another, so as to diminish or destroy its effect.

Reticulated Work. That in which the courses are arranged in a net-like form. The stones are square, and placed lozengewise.

Return. (*Fr.*) The continuation of a moulding, projection, &c., in an opposite direction, as the flank of a portico, &c.

Rib. (*Sax.*) An arched piece of timber sustaining the plaster work of a vault, &c.

Ridge. The top of the roof, which rises to an acute angle.

Rilievo, or Relief. The projecture of an architectural ornament.

Ring. A name sometimes given to the list, cincture, or fillet.

Roman Order. Another name for the Composite.

Rose. The representation of this flower is carved in the centre of each face of the abacus in the Corinthian capital, and is called the *rose* of that capital.

Rustic. The courses of stone or brick, in which the work is jagged out into an irregular surface. Also, work left rough without tooling.

Sagging. The bending of a body in the middle by its own weight, when suspended horizontally by each end.

Salon. (*Fr.*) An apartment for state. or for the reception of paintings, and usually running up through two stories of the house. It may be square, oblong, polygonal, or circular.

Saloon. A lofty hall, usually vaulted at the top, with two stages of windows.

Sash. The wooden frame which holds the glass in windows.

Scaffold. A frame of wood fixed to walls, for masons, plasterers, &c., to stand on.

Scantling. The name of a piece of timber, as of quartering for a partition, when under five inches square, or the rafter, purlin, or pole-plate of a roof.

Scapus. The same as *Shaft* of a column, which see.

Scarfing. The joining and bolting of two pieces of timber together transversely, so that the two appear but as one.

Scotia. The name of a hollowed moulding, principally used between the tori of the base of columns.

Severy, (in Gothic architecture,) a separate portion of a building.

Shaft. That part of a column which is between the base and capital. It is also called the *fust*, as well as *trunk*, of a column.

Shank. A name given to the two interstical spaces between the channels of the triglyph in the Doric frieze.

Shooting. Planing the edge of a board straight, and out of winding.

Shoulder. The plane, transverse to the length of a piece of timber from which a tenon projects.

Shutters. The boards or wainscoting which shut up the aperture of a window.

Sill. The timber or stone at the foot of a window or door; the ground timbers of a frame which support the posts.

Skirtings. The narrow boards which form a plinth round the margin of a floor.

Socle. A square, flat member, of greater breadth than height, usually the same as plinth.

Soffit. The ceiling or under side of a member in an order. It means also the under side of the larmier or corona in a cornice; also, the under side of that part of the architrave which does not rest on the columns. See also *Lacunar*.

Sommer. The lintel of a door, window, &c.; a beam tenoned into a girder, to support the ends of joists on both sides of it.

Spandrel, (in Gothic architecture,) the triangular space enclosed by one side of an arch, and two lines at right angles to each other; one horizontal, and on a level with the apex of the arch, the other perpendicular, and a continuation of the line of the jamb.

Spiral. A curve line of a circular kind, which in its progress recedes from its centre.

Steps. The degrees in ascending a staircase.

Stereobata, or Stylobata. The same as *Entasis*.

Strap. An iron plate, to secure the junction of two or more timbers, into which it is secured by bolts.

Stretching Course. Bricks or stones laid in a wall, with their longest dimensions in the horizontal line.

Surbase. The mouldings immediately above the base of a room.

Systyle. An intercolumniation equal to two diameters.

Table, (in Gothic architecture,) any surface, or flat member.

Tæni. A term usually applied to the lastel above the architrave in the Doric corder.

Templet. A mould used by bricklayers and masons for cutting or